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Linkage of a Physically Based Distributed Watershed Model and a Dynamic Plant Growth Model

Billy E. Johnson and Cade L. Coldren

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Billy E. Johnson

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Cade L. Coldren

Montgomery Watson Harza, Inc.
760 Whalers Way, A-100
Fort Collins, CO 80525

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Abstract: The impact of hydrological alteration on vegetation and of vegetation on water quality can be greatly facilitated by linking existing water engines with general ecosystem models designed to make long-term projections of ecosystem dynamics. This development effort investigated the linkage of soil moisture between the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model and the Ecological Dynamics Simulation (EDYS) model. Conceptually, the EDYS and GSSHA models are well-suited for linkage given that they are both designed to simulate physical or ecological processes at multiple spatial and temporal scales. In particular, EDYS computes small-scale flows (precipitation, interception, evaporation, infiltration, transpiration, and nutrient and contaminant uptake) on a daily basis, and can thereby provide much more accurate estimates of evapotranspiration and water, nutrient, and contaminant uptake by vegetation than would ordinarily be available for calibration of hydrologic models. GSSHA and associated groundwater codes can then provide more accurate estimates of large-scale hydrological and transport processes back to EDYS to effect a system-wide assessment or projection. The long-term objective of this linkage between EDYS and GSSHA is to collaborate with other SWWRP product lines and provide a dynamic eco-hydro modeling capability for regional applications (i.e., the Upper Mississippi, the Everglades, or the Nueces Basin).

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Preface

This report summarizes the linkage of a physically based distributed watershed model and a dynamic plant growth model. This study was performed by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, and Montgomery Watson Harza Global Inc. (MWH) under a Broad Agency Announcement (BAA), BAA FY01 EL-30 Ecological Modeling, entitled "Use of Simulation Modeling to Evaluate Land Management Impact on Watershed Yield in the Lower Edwards Plateau of Texas." Funding was provided under the System-Wide Water Resources Program (SWWRP). Dr. Steven L. Ashby is program manager for SWWRP. Appreciation is extended to all those that provided data for the watershed and plant dynamic simulations.

The Gridded Surface Subsurface Hydrologic Analysis (GSSHA) and the Ecological Dynamic Simulation (EDYS) model were used in this effort. This work was done using data provided for the Cibolo Creek Watershed, located in the vicinity of San Antonio, Texas, by a number of project participants.

Principal Investigators for this study were Dr. Billy E. Johnson, Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Laboratory (EL), ERDC, and Dr. Cade L. Coldren, Montgomery Watson Harza Global, Inc. Dr. Johnson conducted his portion of the study under the general supervision of Dr. Barry W. Bunch, Chief, WQCMB, EL, and under the general supervision of Dr. Richard E. Price, Chief, Environmental Processes and Engineering Division (EPED), EL, and Dr. Beth C. Fleming, Director, EL.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

The impact of hydrological alteration on vegetation and of vegetation on water quality can be greatly facilitated by linking existing water engines with general ecosystem models designed to make long-term projections of ecosystem dynamics. This development effort initially investigated the linkage of soil moisture between the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model and the Ecological Dynamics Simulation (EDYS) model. Conceptually, the EDYS and GSSHA models are well-suited for linkage, given that they are both designed to simulate physical or ecological processes at multiple spatial and temporal scales. In particular, EDYS computes small-scale flows (precipitation, interception, evaporation, infiltration, transpiration, and nutrient and contaminant uptake) on a daily basis, and can thereby provide much more accurate estimates of evapotranspiration and water, nutrient, and contaminant uptake by vegetation than would ordinarily be available for calibration of hydrologic models. GSSHA and associated groundwater codes can then provide more accurate estimates of large-scale hydrological and transport processes back to EDYS to effect a system-wide assessment or projection. The long-term objective of this linkage between EDYS and GSSHA is to collaborate with other System-Wide Water Resources Program (SWWRP) product lines and provide a dynamic eco-hydro modeling capability for regional applications (i.e., the Upper Mississippi, the Everglades, or the Nueces Basin).

2 Model Methodology

This chapter discusses the GSSHA Model (Downer and Ogden 2002), the Nutrient Sub-Models (NSM) (Johnson 2005), and the EDYS model.

GSSHA model

This section will discuss the various methodologies found within GSSHA, that encompass the hydrologic cycle, including

- Precipitation distribution
- Interception
- Infiltration
- Evaporation and evapotranspiration
- Overland flow
- Channel flow
- Groundwater flow
- Coupling of saturated zone and unsaturated zone
- Soil erosion and sediment routing.

Precipitation distribution

Rainfall is a required input within all hydrologic models. Rainfall may be input as spatially and temporally uniform, at a specified rate for a specified duration, for a single event, or rainfall may be input as spatially and temporally varying for any number of rainfall events.

The rainfall interpolation techniques available for spatially varied rainfall are: 1) Inverse Distance Squared Method; or 2) Thiessen Polygon Method. No interpolation method can create information without creating uncertainty. All interpolation methods "estimate" the spatially varied field from point measurements, introducing uncertainty. The Thiessen polygon method is simply a nearest-neighbor approach, while the inverse distance squared method produces smooth fields based on the assumption that the influence of a measured value decreases with the distance from the point of measurement squared.

NEXRAD precipitation estimates can be used in GSSHA, by formatting the data into a GSSHA precipitation file using the RADAR precipitation type

card. When using NEXRAD rainfall estimates, GSSHA assigns a rain gage at the center of each radar data pixel. When combined with Thiessen polygon rainfall interpolation, this reproduces the original radar pixels. Inverse-distance squared interpolation should not be used with radar data.

Interception

The interception of rainfall by vegetation is modeled in GSSHA using the two-parameter method published by Gray (1970). An initial quantity of rainfall (mm) entirely intercepted by foliage and a storage capacity are specified within the model for each land-use type.

Evaporation and evapotranspiration

The evaporation and evapo-transpiration models incorporated in GSSHA allow calculation of the loss of soil water to the atmosphere, improving the determination of soil moistures. Two different evapo-transpiration options are included:

- Bare-ground evaporation from the land-surface using the formulation suggested by Deardorff (1978)
- Evapo-transpiration from a vegetated land-surface utilizing the Penman-Monteith equation (Monteith 1965, 1981).

Variants of these two representations are widely used in land-surface schemes of climate and distributed hydrologic models (e.g., Dickinson et al. 1986; Beven 1979).

Infiltration

Water ponded on overland flow plane cells will infiltrate into the soil as conditions permit. Infiltration is dependent upon soil hydraulic properties and antecedent moisture conditions, which may be affected by previous rainfall, run-on, ET, and the location of the water table. In GSSHA, the unsaturated zone that controls infiltration may be simulated with a one-dimensional (1-D) formulation of Richards' equation (RE), which simulates infiltration, ET, and soil moisture movement in an integrated fashion. Infiltration may also be simulated using traditional Hortonian Green and Ampt (GA) (Green and Ampt 1911) approaches, which are simplifications of RE. There are three optional GA-based methods to calculate infiltration for Hortonian basins: 1) traditional GA infiltration,

2) multi-layer GA, and 3) Green and Ampt infiltration with redistribution (GAR) (Ogden and Saghafian 1997). The traditional GA and multi-layer GA approaches are used for single event rainfall when there are no significant periods of rainfall hiatus. The GAR approach is used when there are significant breaks in the rainfall, or for continuous simulations.

RE is a general equation and can be applied in any type of watershed or conditions. However, the simpler methods based on the GA equation are preferred when runoff is Hortonian, i.e. occurs due to infiltration excess, where the rainfall/run-on of water is greater than the possible infiltration rate. For fine-textured soils the GAR method has been shown to closely mimic the RE solution (Ogden and Saghafian 1997) and when applied in basins identified as Hortonian, the GAR method has been shown to produce results comparable with the RE (Downer and Ogden 2003a).

However, when Hortonian flow is not the predominant mechanism producing stream flow, application of GA type models is ill advised and can result in erroneous results (Downer and Ogden 2002). For cases where Hortonian flow is not the predominant process generating stream flow, the RE should be used and coupled with the saturated groundwater solution as appropriate. Representation of the soil column below each cell with Richards' equation is presented.

Overland flow

Overland flow in GSSHA employs the diffusive wave approximation in two dimensions (x and y). Flow is routed in two orthogonal directions in each grid cell during each time-step. The watershed boundary represents a no-flow boundary for the overland flow routing and when a grid cell lies on the watershed boundary, flow is not routed across the boundary. In GSSHA, $\Delta x = \Delta y$. Inter-cell fluxes in the x and y directions (p and q, respectively) are computed in cell ij from the depth d_{ij} at the n^{th} time level using the Manning equation for the head discharge relationship in the x and y directions. Once water enters a "channel" grid cell, the volume of water is added to the channel system and routed to the watershed outlet. The overland flow routine does allow for depression storage, thus water can pool in a depression until it is able to either build up enough head to overcome the topography, infiltrate into the ground, or evaporate into the air.

Channel flow

GSSHA solves the diffusive wave equation using two-step explicit finite volume schemes to route water for both 1-D channels and two-dimensional (2-D) overland flow, where flows are computed based on heads, and volumes are updated based on the computed flows. Compared with more sophisticated implicit finite difference and finite element schemes, the algorithm used in GSSHA is simple. The friction slope between one grid cell and its neighbors is calculated as the difference in water surface elevations divided by the grid size. Compared with the kinematic wave approach, this diffusive wave approach allows GSSHA to route water through pits or depressions, and regions of adverse slope. The Manning formula is used to relate flow depth to discharge. Use of the Manning formula implies that the flow is turbulent and that the roughness is not dependent on flow depth. Neither of these assumptions may be valid on the overland flow plane. While being simple, the method is powerful because it allows calculations to proceed when only portions of the stream network or watershed are flowing. This is an important attribute, as rainfall may occur on only a portion of the watershed.

The channel routing scheme was developed to allow water to remain in the channel after channel routing ends, and for water to be present in the channel when channel routing begins. Because groundwater may discharge to the stream at any time, channel routing is initiated any time a minimum amount of water is in the channel network. If the channel routing scheme indicates there is no flow in the channel, channel routing is halted during periods outside precipitation events. Fluxes between the stream and the groundwater are still computed and adjustments to the stream volumes are made without routing. If groundwater discharges to the stream, channel routing will resume, but at the groundwater time-step, which is typically larger than the channel routing time-step.

Groundwater flow

Trescott and Larson (1977) described the solution to the two-dimensional free surface groundwater problem, and the efficiency of various solvers. Their methods were largely followed in the development of this portion of the code; exhaustive coverage need not be presented here.

The controlling equation, as developed by Pinder and Bredehoeft (1968), is:

$$\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial x}\left(T_{xy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial y}\left(T_{yx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)=S\frac{\partial h}{\partial t}+W(x,y,t) \quad (1)$$

where T is the transmissivity ($m^2\ s^{-1}$), h is the hydraulic head (m), S is the storage term (dimensionless), and W is the flux term for sources and sinks ($m\ s^{-1}$).

It is assumed that off-diagonal terms are not important and that transmissivity can be expressed as the product of the saturated hydraulic conductivity of the media (K) and the depth of the saturated media (b). For the free surface problem, the head is the surface water elevation (E_{ws}).

$$\frac{\partial}{\partial x}\left(K_{xx}b\frac{\partial E_{ws}}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}b\frac{\partial E_{ws}}{\partial y}\right)=S\frac{\partial E_{ws}}{\partial t}+W(x,y,t) \quad (2)$$

The equation is solved by successive overrelaxation by lines (LSOR) (for example Tannehill et al. (1997)). LSOR was shown by Trescott and Larson (1977) to be capable of solving a variety of difficult groundwater problems, though not necessarily being the most efficient method. With LSOR, the 2-D problem is linearized by solving by rows or by columns. The user specifies solution by rows or by columns and the choice is made to align the direction of solution with the principal direction of flow, x (argument - 1) or y (argument - 2) (Trescott and Larsen 1977).

Coupling of saturated zone and unsaturated zone

In GSSHA, the saturated and unsaturated zones are linked through boundary conditions. When saturated groundwater is simulated, the lower boundary of the unsaturated zone is the saturated groundwater surface. Movement of the saturated groundwater surface according to the solution of the 2-D saturated flow equations requires a flexible spatial discretization for Richards' equation. In extreme cases the groundwater table may rise to the soil surface. In this case the unsaturated zone disappears, and only the saturated flow equations are solved.

When heads from the 2-D unconfined groundwater problem solution are used as the lower boundary condition of the unsaturated groundwater problem, the size of the unsaturated zone in each overland flow cell changes with each saturated groundwater update. Also, the storage term used in the saturated groundwater solution does not account for the water

in the unsaturated zone. After solution of the saturated zone, an extra step is required to account for the water that exists in the unsaturated zone.

Water is exchanged between the saturated and unsaturated zones through fluxes. Fluxes from the saturated zone to the unsaturated zone are added to the source term of the *N-1* unsaturated cell during the next update for the unsaturated zone. The same procedure is used for fluxes to the saturated zone from the unsaturated zone. The formulation of the RE is exploited to correct any temporarily incorrect values of soil moisture or groundwater head. While this method works, it may induce a time lag in the solution.

The simple “bucket” soil moisture accounting routine is used to calculate soil moistures between rainfall events. Soil moisture accounting begins at the end of the rainfall event, when the outlet discharge falls below the event minimum Q. At that time the soil moistures provided by the GAR method are sent to the soil moisture accounting routine and soil moisture calculations proceed until the next specified rainfall event. In the soil moisture accounting routine, the soil moisture is adjusted hourly for losses due to ET only. Even though water may be present on the overland flow plane, flowing and infiltrating, this does not affect the soil moisture accounting calculations. In this respect there is a disconnect between the ET calculations and the infiltration calculations. The storage term used in the saturated groundwater calculations in each cell is assumed to be the effective porosity of the cell minus the initial moisture. The initial moisture is updated at the beginning of each rainfall event. When the groundwater elevations exceed the ground surface elevation, infiltration calculations for the cell cease, and the groundwater surface exchange is calculated as described above. Any time exfiltration occurs, the infiltration and overland flow processes are initiated if they are not already active. These processes remain active as long as exfiltration occurs and until all water on the overland flow plane stops flowing and infiltrating. Infiltration is not calculated for cells in which exfiltration is occurring.

Overland erosion

In order to estimate overland erosion, GSSHA employs an equation based on the work of Kilinc and Richardson (1973). Kilinc and Richardson studied the mechanics of overland soil erosion in at Colorado State University Engineering Research Center in a flume that is 1.2 m deep,

1.5 m wide, and 4.9 m in length. Their investigation resulted in a sediment transport equation of uniform flow sheet and rill erosion on bare sandy soil. Julien et al. (1995) modified the original Kilinc-Richardson equation to expand the applicability of the equation to non-uniform flow with consideration of factors specific to soil and land use (i.e., Universal Soil Loss Equation (USLE) factors, K, C, and P). The K, C, and P factors are empirical coefficients with the same conceptual meaning as those used in the USLE (Renard et al. 1991).

The surface of each grid cell is either eroded or aggraded depending upon the quantity of sediment in suspension and the potential sediment transport rates. This determination is made for three grain sizes (sand, silt, and clay). Conservation of mass of sediment determines how much sediment entering each grid cell stays in suspension, and how much is deposited. The sediment transport capacity is satisfied by sediments already in suspension, previously deposited sediments, and then sediments in the parent material, respectively. If sediments in suspension are unable to satisfy the potential transport rate, the previously deposited sediment is used to satisfy the demand. If there is insufficient previous deposition, then the surface is eroded to meet the demand. If the potential sediment transport rates calculated are insufficient to transport the sediment already in suspension within a grid cell, sediment is deposited on the surface (Johnson 1997).

Channel sediment transport

The present version of GSSHA employs Yang's (1973) unit stream power method for routing sand-size total load in stream channels. Unit stream power is defined as the product of the average flow velocity U and the channel slope S_o. The rate of work done per unit weight of water in transporting sediment is assumed directly related to the rate of work available per unit weight of water. Thus, the total sediment concentration or total bed-material load must be directly related to the unit stream power.

The routing formulation for sand-size sediments is limited to trapezoidal channels with a user-specified maximum allowable depth of degradation in the channel. The channel bed is assumed to be mobile, and the banks are fixed. Degradation continues and bed load is transported at the rate calculated with the Yang (1973) method until the maximum degradation is reached. During degradation, the initial bed width is maintained and

degradation is uniform across the width of the bed. If the channel aggrades, the trapezoidal cross-section is filled. If a channel link has aggraded, and then degrades, the degradation will occur uniformly over the bottom of the trapezoid until the original bed elevation is restored. Further degradation occurs vertically downward from the initial trapezoid bottom width. If a channel degraded below the original bed elevation begins to aggrade, sediment will accumulate uniformly in the rectangular degraded area below the original bed elevation. Once the bed aggrades beyond the original bed elevation, the entire width of the trapezoid is filled.

In the channels, silt and clay size particles are assumed to be in suspension, and are transported as wash load. This treatment implies that the flow is turbulent, and the travel time to the outlet of the catchment is short compared to the settling time, such that particles do not settle in the channel network. This assumption, combined with no bank erosion, results in the channels being neither a source nor sink of fines. Routing of suspended fines is a natural extension of the explicit diffusive-wave channel routing method. Suspended fine sediments are routed as concentrations. The concentration changes as a function of gradients in both concentration and velocity.

Nutrient sub-modules (NSM)

The current SWWRP-NSM nutrient formulations, nitrogen and phosphorus, have been taken primarily from the SWAT model formulation. SWAT models the fate of the nutrients on a distributed scale.

Nitrogen cycle

The three major forms of nitrogen in mineral soils are: 1) organic nitrogen associated with humus, 2) mineral forms of nitrogen held by soil colloids, and 3) mineral forms of nitrogen in solution.

Nitrogen may be added to the soil by fertilizer, manure or residue application, fixation by symbiotic or nonsymbiotic bacteria, and rain. Nitrogen is removed from the soil by plant uptake, leaching, volatilization, denitrification, and erosion. Figure 1 shows the major components of the nitrogen cycle.

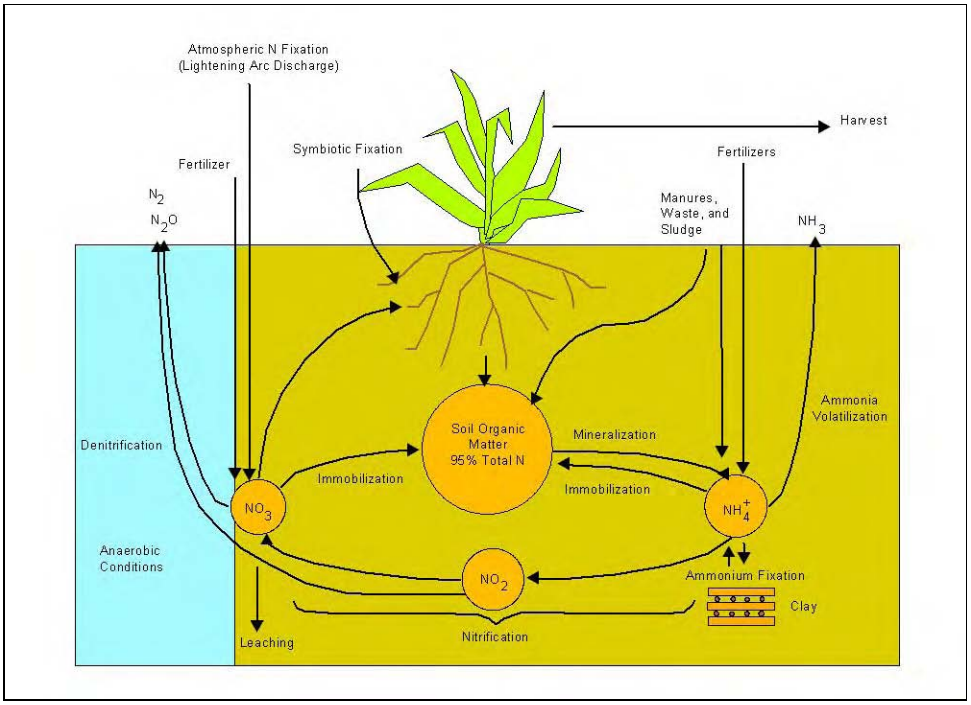

Figure 1. Nitrogen cycle.

Nitrogen is considered to be an extremely reactive element. The highly reactive nature of nitrogen results from its ability to exist in a number of valence states. The valance state or oxidation state describes the number of electrons orbiting the nucleus of the nitrogen atom relative to the number present in an electronically neutral atom. The valence state will be positive as the atom loses electrons and will be negative as the atom gains electrons.

The ability of nitrogen to vary its valence makes it a highly mobile element. Predicting the movement of nitrogen between the different pools in the soil is critical to the successful management of this element in the environment. Five different pools of nitrogen in the soil are shown in Figure 2.

Two pools are inorganic forms of nitrogen, NH_4^+ and NO_3^-, while the other three pools are organic forms of nitrogen. Fresh organic N is associated with crop residue and microbial biomass, while the active and stable organic N pools are associated with the soil humus. The organic nitrogen associated with humus is partitioned into two pools to account for the variation in availability of humic substances to mineralization.

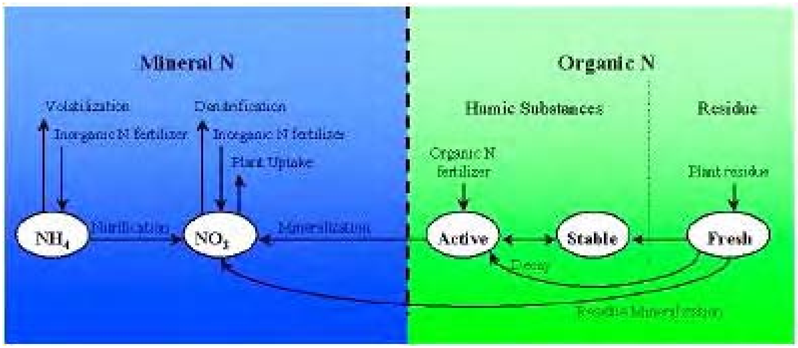

Figure 2. Soil nitrogen pools and processes that move nitrogen in and out of pools.

Mineralization, decomposition, and immobilization

Decomposition is the breakdown of fresh organic residue into simpler organic components. Mineralization is the microbial conversion of organic, plant-unavailable nitrogen to inorganic, plant-available nitrogen. Immobilization is the microbial conversion of plant-available inorganic soil nitrogen to plant-unavailable organic nitrogen.

Bacteria decompose organic material to obtain energy for growth processes. Plant residue is broken down into glucose, which is then converted to energy:

$$C_6H_{12}O_6 + O_2 \xrightarrow{energyreleased} 6CO_2 + 6H_2O \tag{3}$$

The energy released by the conversion of glucose to carbon dioxide and water is used for various cell processes, including protein synthesis. Protein synthesis requires nitrogen. If the residue from which the glucose is obtained contains enough nitrogen, the bacteria will use nitrogen from the organic material to meet the demand for protein synthesis. If the nitrogen content of the residue is too low to meet the bacterial demand for nitrogen, the bacteria will use ammonium and nitrate from the soil solution to meet its needs. If the nitrogen content of the residue exceeds the bacterial demand for nitrogen, the bacteria will release the excess nitrogen into the soil solution as ammonium. General relationships between the C:N ratio and mineralization/immobilization are:

C:N > 30:1	Immobilization occurs, a net decrease in soil ammonia and nitrate.

20:1 <= C:N <= 30:1	Expect no net change; immobilization and mineralization processes are at equilibrium.
C:N < 20:1	Mineralization occurs, a net gain in soil ammonia and nitrate.

Humus mineralization

Nitrogen is allowed to move between the active and stable organic pools in the humus fraction. The amount of nitrogen transferred from one pool to the other is calculated as a function of a rate constant, amount of nitrogen in the active organic pool, fraction of humic nitrogen in the active organic pool, and the amount of nitrogen in the stable organic pool.

When the amount of nitrogen to be transferred is positive, nitrogen is moving from the active organic pool to the stable organic pool. When the amount of nitrogen to be transferred is negative, nitrogen is moving from the stable organic pool to the active organic pool.

Mineralization from the humic active organic N pool is calculated as a function of a rate constant for mineralization of the humus active organic nutrients, the nutrient cycling temperature factor, the nutrient cycling water factor, and the amount of nitrogen in the active organic pool. Nitrogen mineralized from the humus active organic pool is added to the nitrate pool in the layer.

Residue decomposition and mineralization

Decomposition and mineralization of the fresh organic nitrogen pool will be allowed only in the first soil layer. Decomposition and mineralization are controlled by a decay rate constant that is updated daily. The decay rate constant is calculated as a function of the C:N ratio and the C:P ratio of the residue, temperature, and soil water content.

The decay rate constant defines the fraction of residue that is decomposed and is a function of the rate constant for mineralization of the residue fresh organic nutrients, the nutrient cycling residue composition factor, the nutrient cycling temperature factor, and the nutrient cycling water factor. The nutrient cycling residue composition factor is a factor of the C:N ratio of the residue in the soil layer and the C:P ratio of the residue in the soil layer. Mineralization from the residue fresh organic N is a function

of the residue decay rate constant and the nitrogen in the fresh organic pool. Nitrogen mineralized from the fresh organic pool will be added to the nitrate pool in the layer. Decomposition from the residue fresh organic N pool is a function of the residue decay rate constant and the nitrogen in the fresh organic pool.

Nitrification and ammonia volatilization

Nitrification is a two-step bacterial oxidation of NO_4^+ and NO_3^-:

Step 1: $$2NH_4^+ + 3O_2 \xrightarrow{-12e^-} 2NO_2^- + 2H_2O + 4H^+$$ (Nitrosomonas)

Step 2: $$2NO_2^- + O_2 \xrightarrow{-4e^-} 2NO_3^-$$ (Nitrobacter)

Ammonia volatilization is the gaseous loss of NH_3 that occurs when ammonium is surface applied to a calcareous soil or when urea, $(NH_2)_2CO$, is surface applied to any soil.

Ammonium surface applied to a calcareous soil:

Step 1: $$CaCO_3 + 2NH_4^+X \longleftrightarrow (NH_4)_2CO_3 + CaX_2$$

Step 2: $$(NH_4)CO_3 \longleftrightarrow 2NH_3 + CO_2 + H_2O$$

Urea surface applied to any soil:

Step 1: $$(NH_2)_2CO + 2H_2O \xleftrightarrow{ureaseenzyme} (NH_4)_2CO_3$$

Step 2: $$(NH_4)_2CO_3 \longleftrightarrow 2NH_3 + CO_2 + H_2O$$

Within the formulation, nitrification and ammonia volatilization will be simulated using a combination of methods developed by Reddy et al. (1979) and Godwin et al. (1984). The total amount of nitrification and ammonia volatilization will be calculated, and then partitioned between the two processes. Nitrification is a function of soil temperature and soil water content, while ammonia volatilization is a function of soil temperature and depth. Three coefficients will be used in the nitrification/ volatilization algorithms to account for the impact of these parameters. It

will be assumed that nitrification/volatilization occurs only when the temperature of the soil layer exceeds 5 ^{o}C.

The nitrification/volatilization temperature factor is a function of the soil temperature. The nitrification soil water factor is a function of the soil water content, the amount of water held in the soil layer at wilting point content, and the amount of water held in the soil layer at field capacity water content. The volatilization depth factor is a function of the depth from the soil surface to the middle of the layer. The impact of environmental factors on nitrification and ammonia volatilization, in a given layer, is defined by the nitrification regulator and volatilization regulator. The nitrification regulator is a factor of the nitrification/volatilization temperature factor and the nitrification soil water factor. The volatilization regulator is a function of the nitrification/volatilization temperature factor and the volatilization depth factor. The total amount of ammonium lost to nitrification and volatilization is calculated using a first-order kinetic rate equation (Reddy et al. 1979), which is a function of the amount of ammonia, the nitrification regulator, and the volatilization regulator. To partition nitrogen between nitrification and volatilization, the expression by which ammonia is multiplied is solved using each regulator individually to obtain a fraction of ammonium removed by each process. The amount of nitrogen removed from the ammonium pool by nitrification and volatilization is thus a function of these computed fractions.

Denitrification

Denitrification is the bacterial reduction of nitrate, NO_3^-, to N_2 or N_2O gases under anaerobic (reduced) conditions. Denitrification is a function of water content, temperature, presence of a carbon source, and nitrate.

In general, when the water-filled porosity is greater than 60 percent, denitrification will be observed in a soil. As soil water content increases, anaerobic conditions develop due to the fact that oxygen diffuses through water 10,000 times slower than through air. Because the rate of oxygen diffusion through water slows as the water temperature increases, temperature will also influence denitrification.

In this formulation, the amount of nitrate lost to denitrification is a function of the amount of nitrate, the nutrient cycling temperature factor, and the amount of organic carbon.

Nitrogen in rainfall

Lightning discharge converts atmospheric N_2 to nitric acid, which can then be transferred to the soil with precipitation. The chemical steps involved are:

Step 1: $N_2 + O_2 \xrightarrow{arc\ of\ electricity} 2NO$ (monoxide)

Step 2: $2NO + O_2 \longrightarrow NO_2$ (dioxide)

Step 3: $3NO_2 + H_2O \longrightarrow 2HNO_2 + NO$ (nitric acid and monoxide)

More nitrogen will be added to the soil with rainfall in areas with a high amount of lightning activity than in areas with little lightning.

The amount of nitrate added to the soil in rainfall is a function of the concentration of nitrogen in the rain and the amount of precipitation on a given day. The nitrogen in rainfall is added to the nitrate pool in the top 10 mm of soil.

Phosphorus cycle

Although plant phosphorus demand is considerably less than nitrogen demand, phosphorus is required for many essential functions. The most important of these is its role in energy storage and transfer. Energy obtained from photosynthesis and metabolism of carbohydrates is stored in phosphorus compounds for later use in growth and reproductive processes.

The three major forms of phosphorus in mineral soils are organic phosphorus associated with humus, insoluble forms of mineral phosphorus, and plant-available phosphorus in soil solution. Phosphorus may be added to the soil by fertilizer, manure, or residue application. Phosphorus is removed from the soil by plant uptake and erosion. Figure 3 shows the major components of the phosphorus cycle.

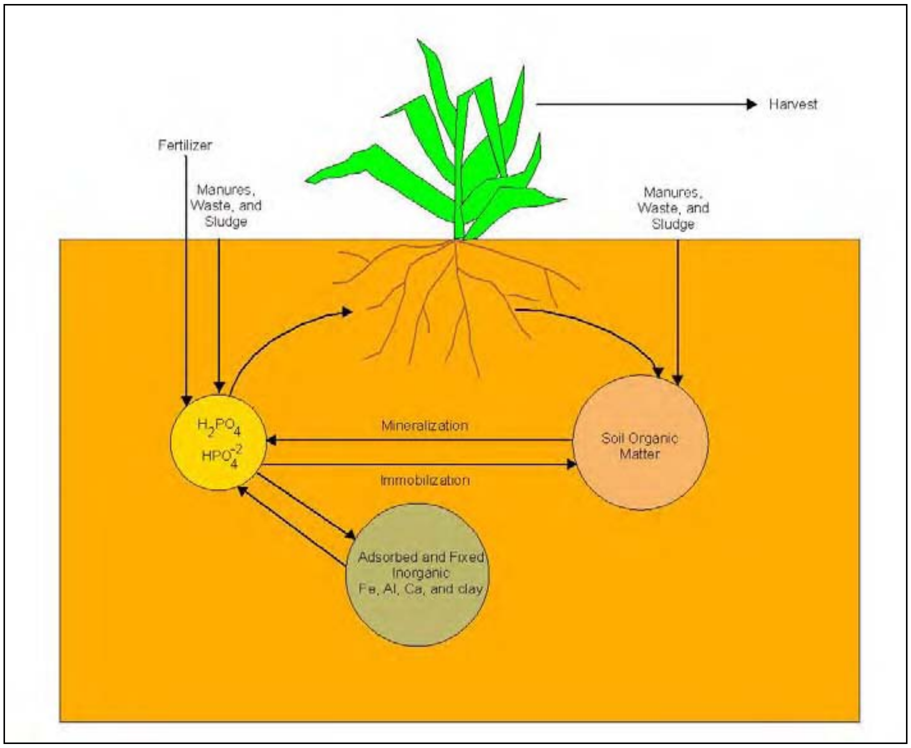

Figure 3. Phosphorus cycle.

Unlike nitrogen, which is highly mobile, phosphorus solubility is limited in most environments. Phosphorus combines with other ions to form a number of insoluble compounds that precipitate out of solution. These characteristics contribute to a buildup of phosphorus near the soil surface that is readily available for transport in surface runoff. In addition to precipitating, phosphorus adsorbs to soil solids and can be transported via soil erosion. Sharpley and Syers (1979) observed that surface runoff is the primary mechanism by which phosphorus is exported from most catchments. Six different pools of phosphorus are represented in the formulation (Figure 4).

Three pools are inorganic forms of phosphorus, while the other three pools are organic forms of phosphorus. Fresh organic P is associated with crop residue and microbial biomass, while the active and stable organic P pools are associated with the soil humus. The organic P associated with humus is partitioned into two pools to account for the variation in availability of humic substances to mineralization. Soil inorganic P is divided into solution, active, and stable pools. The solution pool is in rapid equilibrium (several days or weeks) with the active pool. The active pool is in slow equilibrium with the stable pool.

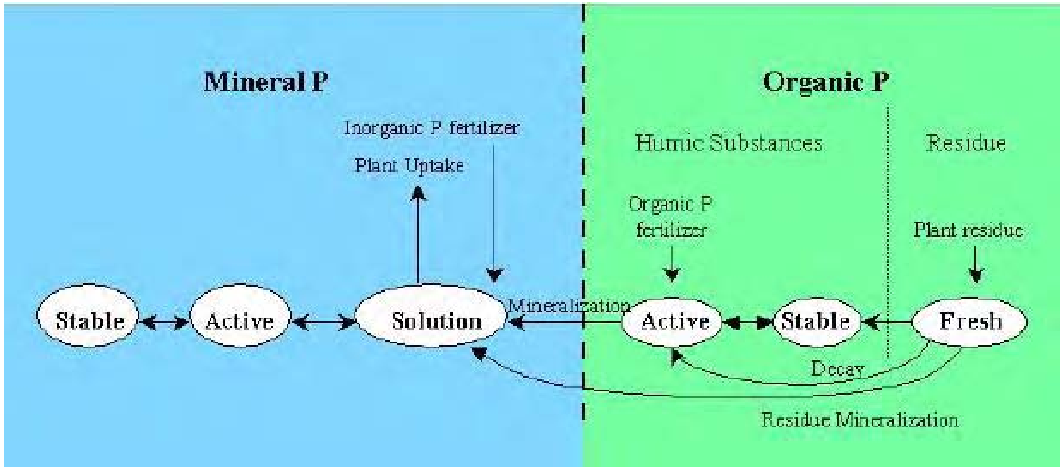

Figure 4. Soil phosphorus pools and processes that move P in and out of pools.

Mineralization, decomposition, and immobilization

The phosphorus mineralization algorithms within this formulation are net mineralization algorithms which incorporate immobilization into the equations. The phosphorus mineralization algorithms developed by Jones et al. (1984) are similar in structure to the nitrogen mineralization algorithms. Two sources are considered for mineralization: 1) the fresh organic P pool associated with crop residue and microbial biomass; and 2) the active organic P pool associated with soil humus. Mineralization and decomposition are allowed to occur only if the temperature of the soil layer is above 0 ^{o}C.

Mineralization and decomposition are dependent on water availability and temperature. Two factors are used in the mineralization and decomposition equations to account for the impact of temperature and water on these processes.

Humus mineralization

Phosphorus in the humus fraction is partitioned between the active and stable organic pools using the ratio of humus active organic N to stable organic N. The amount of phosphorus in the active and stable organic pools is a function of the amount of humic phosphorus, the amount of nitrogen in the active organic pool, and the amount of nitrogen in the stable organic pool. Mineralization from the humus active organic P pool is a function of the rate coefficient for mineralization of the humus active organic nutrients, the nutrient cycling temperature factor, the nutrient cycling water factor, and the amount of phosphorus in the active organic

pool. Phosphorus mineralized from the humus active organic pool is added to the solution P pool.

Residue decomposition and mineralization

Decomposition and mineralization of the fresh organic phosphorus pool is allowed only in the first soil layer. Decomposition and mineralization are controlled by a decay rate constant that is continuously updated.

Sorption of inorganic P

Many studies have shown that after an application of soluble P fertilizer, solution P concentration decreases rapidly with time due to reaction with the soil. This initial “fast” reaction is followed by a much slower decrease in solution P that may continue for several years (Barrow and Shaw 1975; Munns and Fox 1976, Rajan and Fox 1972, Sharpley 1982). In order to account for the initial rapid decrease in solution P, this formulation assumes that a rapid equilibrium exists between solution P and an “active” mineral pool. The subsequent slow reaction is simulated by the slow equilibrium assumed to exist between the “active” and “stable” mineral pools. The algorithms governing movement of inorganic phosphorus between these pools are taken from Jones et al. (1984).

Equilibrium between the solution and active mineral pool is governed by the phosphorus availability index. This index specifies the fraction of fertilizer P that is in solution after an incubation period, i.e., after the rapid reaction period.

The movement of phosphorus between the solution and active mineral pools will be governed by the equilibrium equations, which are a function of the amount of phosphorus in the active mineral pool, the amount of phosphorus in solution, and the phosphorus availability index. When the phosphorus amount is positive, phosphorus is being transferred from solution to the active mineral pool. When the phosphorus amount is negative, phosphorus is being transferred from the active mineral pool to solution. Note that the rate of flow from the active mineral pool to solution is one tenth the rate of flow from solution to the active mineral pool.

This formulation simulates slow phosphorus sorption by assuming the active mineral phosphorus pool is in slow equilibrium with the stable

mineral phosphorus pool. At equilibrium, the stable mineral pool is four times the size of the active mineral pool.

When not in equilibrium, the movement of phosphorus between the active and stable mineral pools is a function of the slow equilibrium rate constant, the amount of phosphorus in the active mineral pool, and the amount of phosphorus in the stable mineral pool.

EDYS model

The Ecological Dynamics Simulation (EDYS) model is a PC-based, mechanistic, spatially explicit, and temporally dynamic simulation model developed by Terry McLendon, Michael Childress, and Cade Coldren (Childress and McLendon 1999, Childress et al. 1999a, 1999b). EDYS simulates changes in soil, water, plant, animal, and landscape components resulting from natural and anthropogenic ecological stressors (McLendon et al. 1999, Childress et al. 2002). EDYS has been applied to over 40 ecological communities, including deserts, forests, grasslands, shrublands, wetlands, salt marshes, woodlands, and highly disturbed areas. Application locations include Arizona, California, Colorado, Maine, Montana, Nevada, New Mexico, Texas, Utah, Washington, Wyoming, Australia, and Indonesia.

EDYS consists of Climate, Soil, Hydrologic, Plant, Animal, Stressor, Spatial, Landscape, Management, and Simulation Control modules.

- In the Climatic Module, precipitation and wind inputs can be historical, stochastically generated, or a combination of both.
- The Soil Module is divided into layers (horizons, subhorizons, or artificial layers), the number, depth, and physical and chemical characteristics of which are site-specific for each application.
- The Hydrologic Module provides for infiltration and water movement through the soil profile, surface movement of water, surface erosion, sediment transport, subsurface movement of water, and changes in water quality.
- The Plant Module includes above- and below-ground components for each species included in each user-defined suite. Plant growth is dynamic in relation to plant components (roots, trunk, stems, leaves, seeds, and standing dead), season, resource requirements (water,

nutrients, sunlight), and stressors (e.g., herbivory, competition, fire, trampling, chemical contaminants).

- The Animal Module consists of basic population parameters and diet attributes (preferences, utilization potential, competitive success) for each species (e.g., insects, rodents, native ungulates, livestock).
- The Stressor Module includes drought, nutrient availability, fire, herbivory, contaminants, shading, and competition for soil moisture and nutrients.
- The Spatial Module allows growth of individual plants (e.g., trees) and distribution patterns (e.g., colonies, fire patterns, soil heterogeneity) to be explicitly represented in the simulations.
- The Landscape Module allows for multi-scale simulations: plots (typically 1-100 m^2), communities (typically 1-100 hectares), and landscapes (1 km^2 and larger).
- The Management Module allows simulation of a variety of management activities, including agriculture, revegetation, weed and brush control, construction, reclamation, recreation, and military training.
- The Simulation Control Module coordinates the timing of simulation of ecological processes, allowing time-steps for different processes to vary from daily (e.g., precipitation events, plant water demand, fire, herbivory), to monthly (e.g., species composition), to annual and longer (e.g., climatic cycles).

EDYS structure

EDYS is designed to simultaneously simulate ecosystem dynamics at three different spatial scales: plots, communities, and landscapes (Figure 5).

Plot-level dynamics in EDYS simulate ecological dynamics at the small scale (typically, 1 m^2 to 100 m^2), including biomasses of different plant species over time (bar chart in Figure 5). Most of the mechanistic processes in EDYS related to plants (e.g., growth, water and nutrient uptake, and competition) and soils (e.g., water and nutrient transport through the profile, decomposition) are implemented at this level (Figure 6).

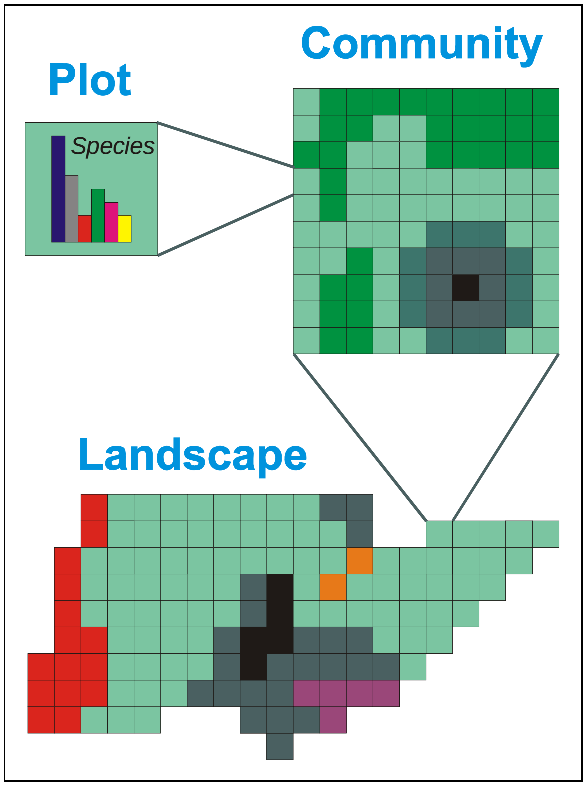

Figure 5. Multiple scales represented in EDYS simulations.

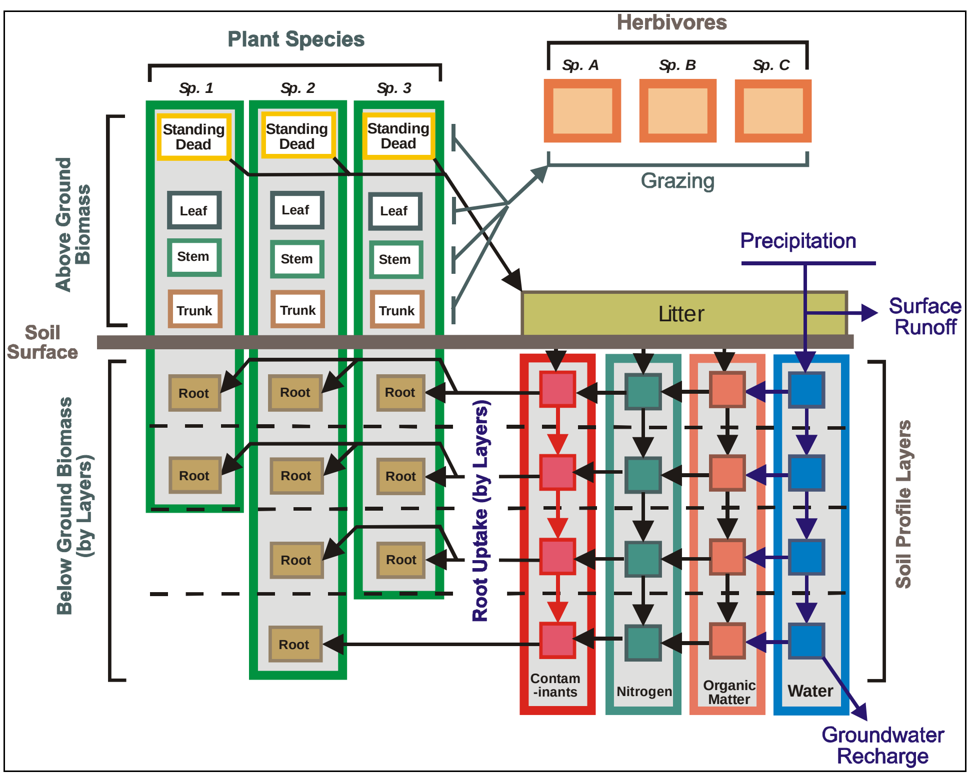

Figure 6. Plot-level structure of the EDYS general ecosystem model.

Different plots are represented as cells in the community grid (Figure 5). The Community Module focuses on spatial patterns and dynamics from the plot to the community scales. These include spatial heterogeneity in soils, plants, and stressors among plots within the community, stressors such as fire propagation, grazing, and lateral flow of surface and subsurface water and materials, and important spatial patterns such as vegetation cover, habitats, and topography.

In an analogous manner, communities are the basic units in the Landscape Grid (Figure 5). This largest scale focuses on ecological processes operating at large spatial scales (1 km^2 and larger). These include fire initiation regimes, climatic regimes, watershed-level water movement and transport of materials, and management practices such as revegetation, grazing operations, irrigation, weed control, and military training.

EDYS soil module

Soil profiles in EDYS are comprised of multiple layers, the number of which may vary between soil series and applications (Figure 6). The following characteristics are used to describe each layer:

- Depth
- Texture (% sand, silt, and clay)
- Rock and gravel content
- Water-holding capacities (wilting point, field capacity, saturation)
- Organic matter content
- Nutrient content
- Compaction
- Chemical composition (e.g., pH and constituent concentrations).

Water-holding capacities are calculated as follows (all equations derived from Saxton et al. 1986). For all calculations, *Sand* is percent sand and *Clay* is percent clay.

Saturation:

$$SAT = 0.332 - (7.251e^{-4} * (Sand)) + 0.1276 * \log_{10}(Clay) \qquad (4)$$

Field Capacity:

$$FC = \left(\frac{0.3333}{A}\right)^{\left(1/B\right)} \tag{5}$$

$$A = e^{\left(-4.396-(0.0715*Clay)-\left(0.000488*Sand^2\right)-\left(0.00004285*Sand^2*Clay\right)\right)} \tag{6}$$

$$B = -3.140 - \left(0.00222*\left(Clay^2\right) - \left(0.00003484*\left(Sand^2\right)*Clay\right)\right) \tag{7}$$

Wilting Point:

$$WP = \left(\frac{15.0}{A}\right)^{\left(1/B\right)} \tag{8}$$

$$A = e^{\left(-4.396-(0.0715*Clay)-\left(0.000488*Sand^2\right)-\left(0.00004285*Sand^2*Clay\right)\right)} \tag{9}$$

$$B = -3.140 - \left(0.00222*\left(Clay^2\right) - \left(0.00003484*\left(Sand^2\right)*Clay\right)\right) \tag{10}$$

EDYS hydrological module

Hydrological dynamics are central in the EDYS model. Available water is often a limiting resource for plant growth and decomposition, and provides transport for nutrients and contaminants. Precipitation and groundwater elevation are external inputs to the EDYS simulations, so different precipitation patterns and groundwater contours are evaluated using a series of scenarios. Precipitation inputs are typically derived from historical data from nearby weather stations, but may also be stochastically generated, with scenarios representing average, wet, and dry periods.

In addition to precipitation, there are numerous other hydrological flows at the plot level in the EDYS model (Figure 7). Rather than assigning a fixed percentage of precipitation to interception, evaporation, and transpiration, EDYS calculates these losses on a daily basis as functions of current plant biomass and existing soil moisture. In particular, transpiration is computed as uptake of water from different soil horizons based on the presence of roots in each horizon and the daily water demand of each plant species. Infiltration into the soil profile is simulated using a simple

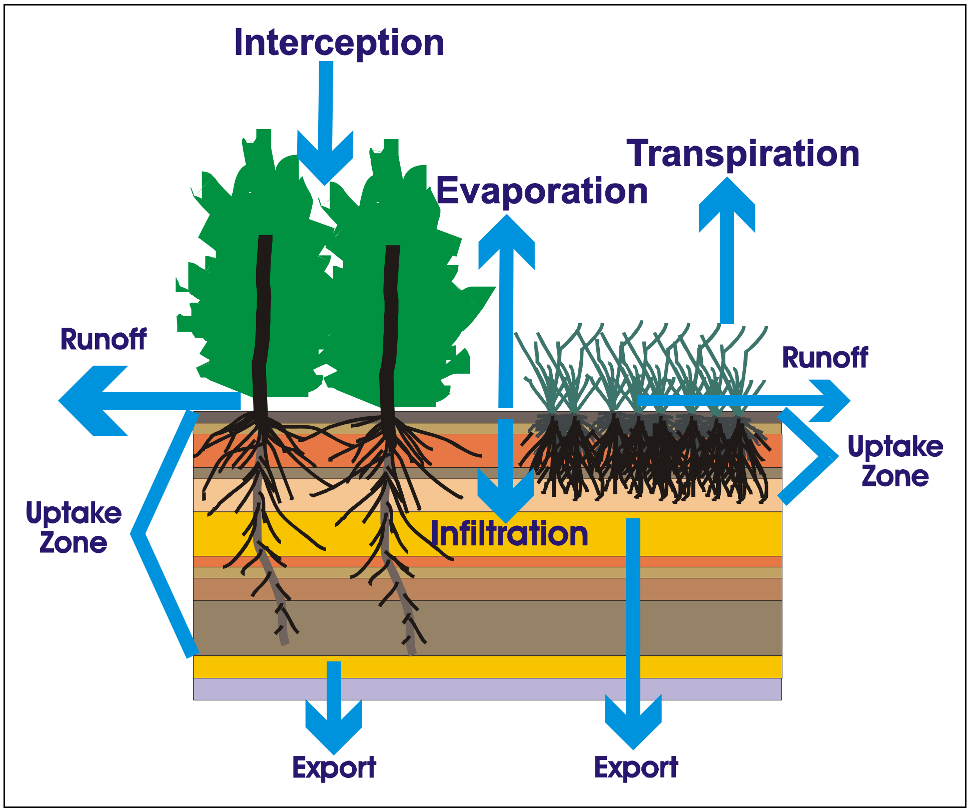

Figure 7. Plot-level hydrological dynamics in the EDYS model.

tipping bucket algorithm based on permeabilities and water-holding capacities of each soil horizon. EDYS also simulates surface runoff and shallow subsurface vertical and lateral flows among plot cells in the landscape grid (Figure 8) and calculates recharge and uptake of groundwater in each cell across the landscape.

EDYS plant module

The Plant Module models plant dynamics by simulating individual species responses to resource availability, competition, and various stressors. Each species is represented by its constituent components (coarse roots, fine roots, trunks, stems, leaves, seeds, and standing dead material). Species are also represented by age classes (i.e., mature plants, seedlings, and saplings) and by a seedbank. A series of plant parameters (Table 1) governs all plant mechanisms, including growth, competition for resources (light, water, and nutrients), and response to stressors (e.g., chemical contaminants, fire, herbivory, and military training).

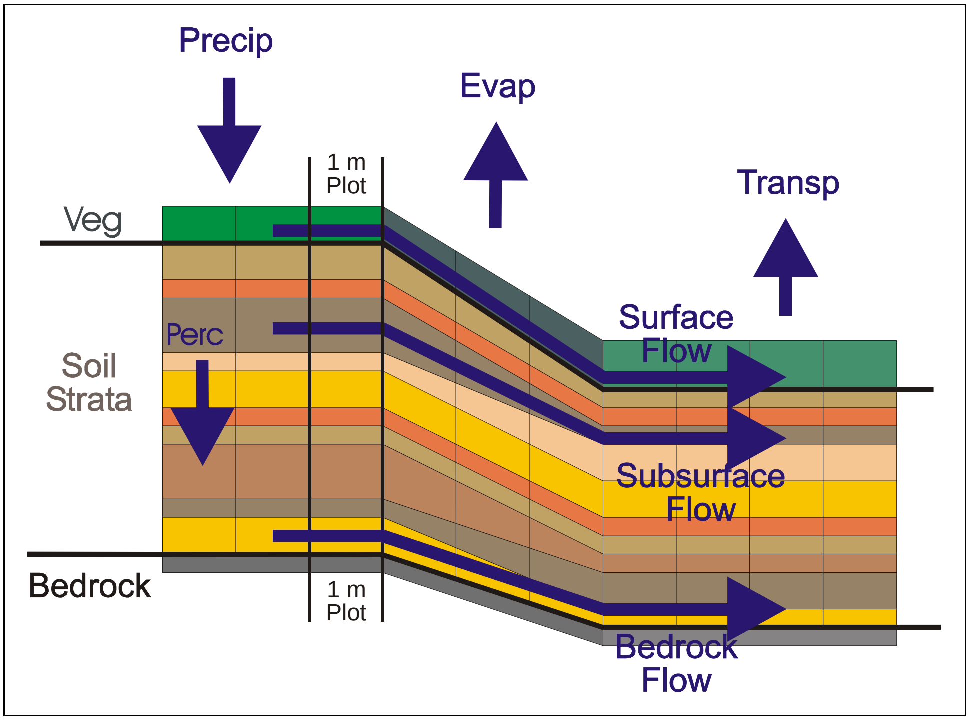

Figure 8. Landscape-level hydrology in the EDYS model.

Table 1. Plant parameters used by EDYS to simulate plant dynamics.

Parameter	Function within EDYS
Mature allocation	Distribution of biomass by plant component for mature plants
Current allocation	Distribution of biomass by plant component for new growth
Green-out allocation	Distribution of biomass by plant component for new growth at green-out
Seed month allocation	Distribution of biomass by plant component for new growth when seeds are being produced
Initial nitrogen concentration	Initial nitrogen concentration by plant component
Maintenance nitrogen concentration	Nitrogen concentration by plant component required for maintenance
Nitrogen resorption	Proportion of nitrogen that may be resorbed prior to senescence
Root architecture	Distribution of root biomass by soil layer
Maximum rooting depth	Maximum possible rooting depth
Root saturation death loss	Proportion of root biomass loss due to saturated soil conditions
Root uptake capacity	Proportion of monthly water demand that may be obtained in a single day
Root competitive efficiency	Relative competitive efficiency for obtaining soil moisture
Green-out month	Start of the growing season
Seed germination month	Months when seeds may germinate
Seed set month	Months when plants may produce seeds
Die-back month	Month when dormancy begins

(continued)

Parameter	Function within EDYS
Dry weight/wet weight	Dry weight to wet weight conversion factor
Moisture interception	Conversion factor for aboveground biomass to precipitation loss from interception
Trunk biomass/basal cover	Conversion factor for trunk biomass to basal cover
Maintenance water use	Water demand for maintenance of old growth
New biomass maintenance water use	Water demand for maintenance of new biomass
Water use efficiency	Amount of water needed to produce 1 gm of new growth
Green-out water use	Relative water use efficiency for green-out conditions
Maximum old-growth drought loss	Maximum biomass loss of old growth during drought conditions
Maximum growth rate	Maximum growth rate that may be achieved under ideal conditions
Maximum biomass limit	Maximum aboveground biomass that may be achieved under ideal conditions
Monthly maximum growth rate	Seasonal changes in maximum growth potential
Plant part productivity	Relative contribution by plant component to new growth, based on distribution of photosynthetic material within a plant
Green-out plant part productivity	Relative contribution by plant component to new growth during green-out conditions
Light competition factor	Relative sensitivity to shading by other species in the community
Maximum growing season root:shoot	Maximum allowable root:shoot ratio
Green-out root:shoot trigger	Minimum root:shoot ratio that will trigger green-out conditions
Maximum 1-month seed germination	Proportion of seed bank that may germinate during any one month
Maximum 1st month seedling growth	Maximum seedling growth rate during first month after germination
End of growing season die-back	Proportion of biomass loss due to senescence
Die-back fate	Fate of biomass when die-back occurs
Losses to fire events	Proportion of biomass lost by plant component to fire events
Fuel combustibility factor	Contribution by plant component to fuel load
Loss to trampling or single vehicle pass	Proportion of biomass lost by plant component to trampling or to a single vehicle pass

EDYS spatial module

EDYS represents spatial heterogeneity by assigning plot types to multiple grid cells across the simulation landscape. Each plot type represents a unique combination of soils and plants. Additionally, each cell is assigned topographic data (e.g. elevation, slope, aspect). Patterns of land use are imposed upon the vegetation and topography. This multi-tiered approach allows EDYS to represent disturbance patterns and management activities in a realistic, spatially explicit manner.

EDYS nutrient dynamics

The primary nutrient modeled in EDYS is nitrogen (Figure 9), largely because it is an important factor in driving plant successional dynamics. Other nutrients, such as phosphorous, can be simulated by EDYS if their dynamics are of importance for a particular application.

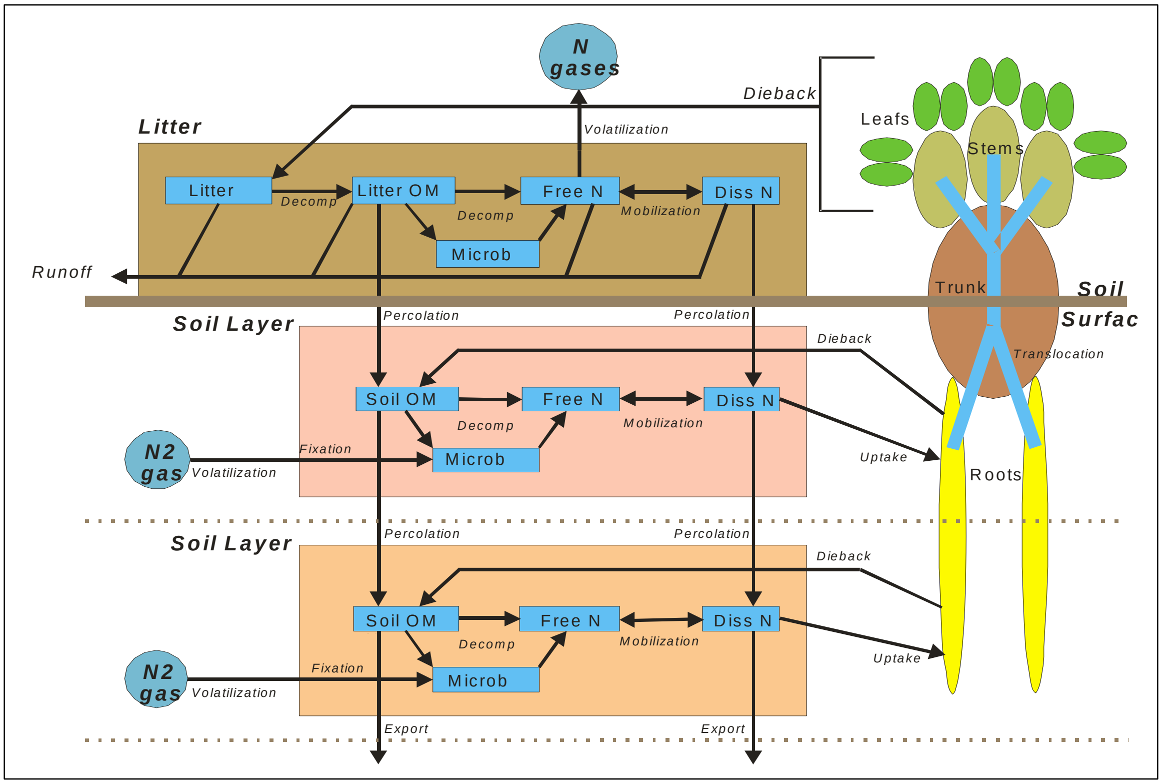

Figure 9. Plot-level nitrogen dynamics in EDYS.

EDYS flowchart

EDYS uses several time-steps, ranging from days to years, to simulate different ecological and hydrological processes during each simulation run (Figure 10). Hydrological processes are for the most part computed daily, along with plant uptake of water and nutrients. Other plant dynamics, such as growth and seed set, are computed monthly and then disaggregated during the month on a daily basis. Management practices, such as physical disturbances, recreational use, and natural fire, are treated in the same manner.

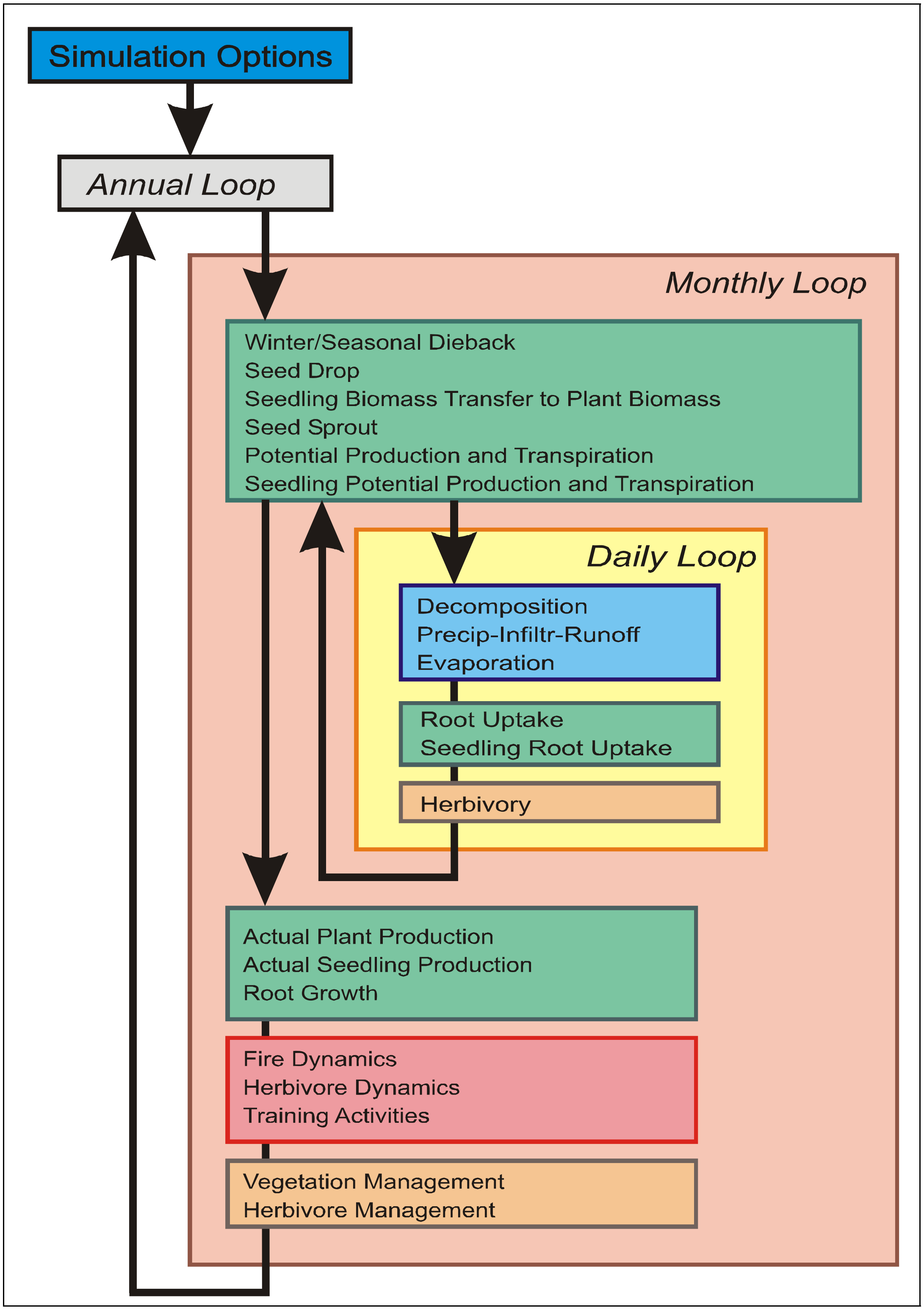

Figure 10. Simulation flowchart for the EDYS model.

3 Manual Linkage Setup

The current approach to linking GSSHA with EDYS involves the transfer of soil moisture values via output files between the two modeling systems. The first transfer occurs at the start of an event to be simulated by GSSHA, when EDYS outputs the current soil moisture conditions prior to launching GSSHA. After GSSHA terminates, the second transfer occurs when EDYS reads a GSSHA output file containing soil moisture conditions at the conclusion of the precipitation event. EDYS then uses those data to set soil moisture levels prior to continuing its daily operations.

The steps below detail the actual sequence of events during a GSSHA-EDYS linked run:

1. At the start of the simulation, EDYS reads the "event_all.gag" file to compile a list of precipitation events to be simulated by GSSHA and builds a matrix used by EDYS to control the simulation sequence. This matrix includes event year, month, day, and duration (in days).
2. If not previously configured, EDYS will create the necessary directory structures for saving GSSHA outputs.
3. At the start of a precipitation event:
    a. EDYS reads the effective porosity grid "ep10.dat."
    b. EDYS reads the residual saturation grid "rs.dat."
    c. EDYS writes out current soil moisture conditions to the initial soil moisture "ism.dat" file. Soil depth for reporting is set at 400 mm. For each grid cell, the following processing steps are conducted:
        - Soil moisture is totaled for all layers contained in the top 400 mm.
        - Percent soil moisture by depth is calculated and multiplied by the effective porosity.
        - Soil moisture is then compared to the residual saturation value. If less than residual saturation for that cell, then soil moisture is set to "residual saturation + 0.01."
    d. EDYS launches GSSHA for that event.
4. After GSSHA completes execution:
    a. EDYS finds the last surface moisture output file generated by GSSHA.
    b. EDYS reads the surface moisture value for each cell.
    c. Moisture is converted to percentage of soil moisture by dividing by the effective porosity.

   d. EDYS sets moisture content for each soil layer contained within the 400-mm depth. If the content exceeds saturation level, then moisture is set to saturation.
5. EDYS then continues execution on the next day using the updated soil moisture values.

Existing data transfer

Currently, the mechanism has been developed whereby soil moisture maps can be transferred between the two modeling systems. While no other data layers are being transferred, it is relatively simple to add more water budget and ecological data layers to the data transfer modules.

Future data transfer

Future data transfers will encompass a wide variety of data types. Infiltration and Evapotranspiration data layers will be transferred in order to perform long-term simulations. Parameters associated with land use and soil type will allow one to alter the hydraulic flow computations based upon land use changes and training scenarios. As the nutrient sub-models become more developed, plant uptake and biomass loading will become available and will allow better tracking of nutrient fate and transport throughout the watershed.

4 Case Study - Cibolo Creek Watershed

Watershed description

The Cibolo Creek Watershed lies along the southern edge of the Edwards Plateau Ecoregion in central Texas, also known locally as the Texas Hill Country. The topography in this ecoregion is hilly and is commonly dissected by streams. Average rainfall across the Edwards Plateau ranges from 16 to 33 in. annually. Soils are shallow and usually underlain with limestone or caliche.

The Cibolo Creek watershed encompasses portions of Bandera, Bexar, Comal, and Kendall counties and includes the communities of Boerne and Bulverde. The model domain extends roughly from IH-10 east of San Antonio west to approximately 11 miles (18 km) west of Boerne, totaling 70,770 hectares (174,877 acres). Elevations within the model domain, Figure 11, range from 228 m (748 ft.) to 612 m (2008 ft.). Dominant native vegetation is a mixture of Ashe juniper (*Juniperus ashei*) – live oak (*Quercus virginiana*) woodlands and grasslands.

Hydrologic data input

The hydrologic data used in the distributed rainfall runoff modeling effort were furnished by engineers and scientists at the U.S. Geological Survey (USGS) and Montgomery Watson Harza Global, Inc (MWH). The following figures and tables describe the input data used to compute surface runoff and soil moisture contents. The soil moisture data layers were exchanged between GSSHA and EDYS in an effort to develop the proper data exchange protocol such that future water and nutrient data layers can be exchanged between the two modeling systems during long-term simulations.

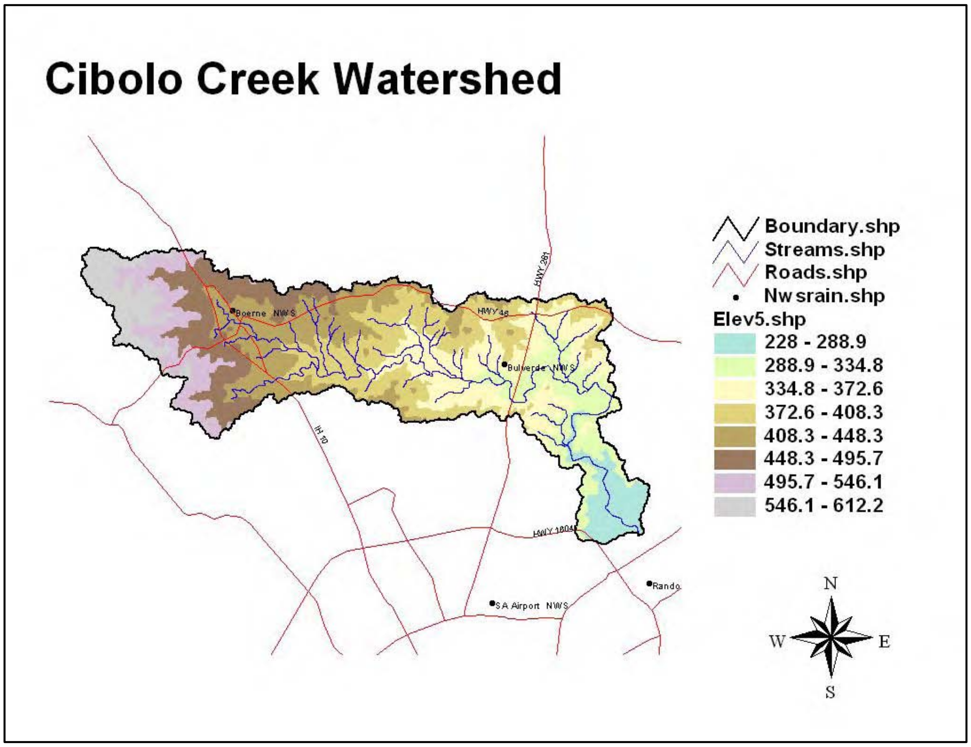

Figure 11. Digitial elevation map (120 m) for Cibolo Creek Watershed.

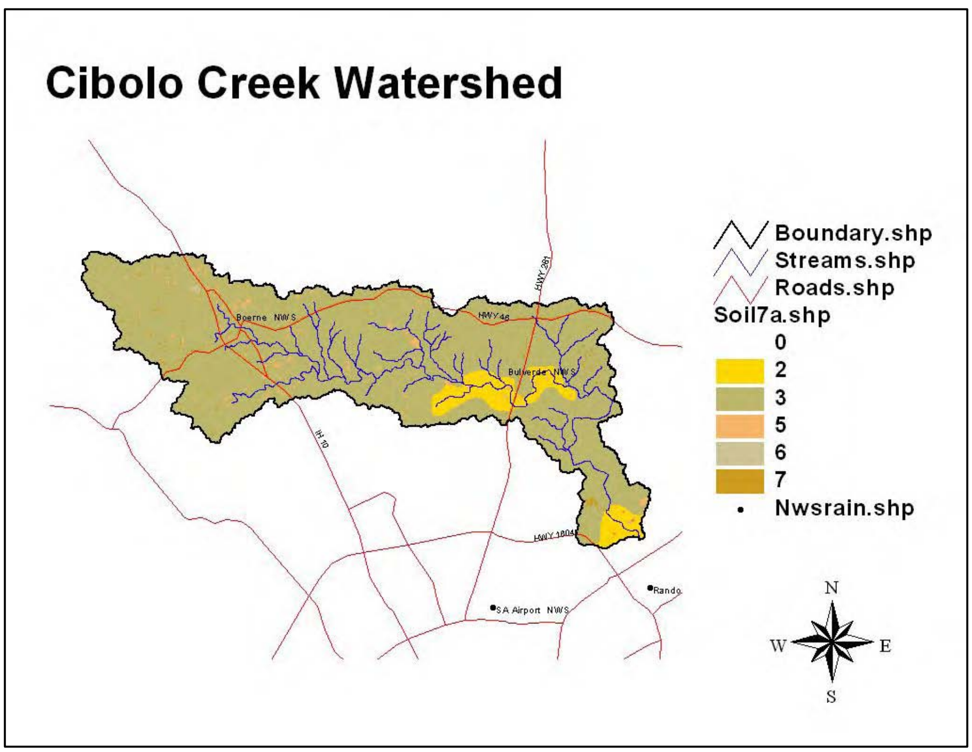

Figure 12. Soil texture map for Cibolo Creek Watershed.

Table 2. Estimated soil parameters.

Map ID	Description	Estimated Soil Texture	Hydraulic Conductivity cm/h	Capillary Head cm	Effective Porosity
2	brackett-comfort-real (tarrant-brackett)	Clay Loam	0.20	20.88	0.390
3	hockley-web-crockett	Sandy Loam	0.52	18.33	0.486
5	LULC 11 (Residential)		0.03	31.63	0.385
6	LULC 16 (Commercial)		0.01	31.63	0.385

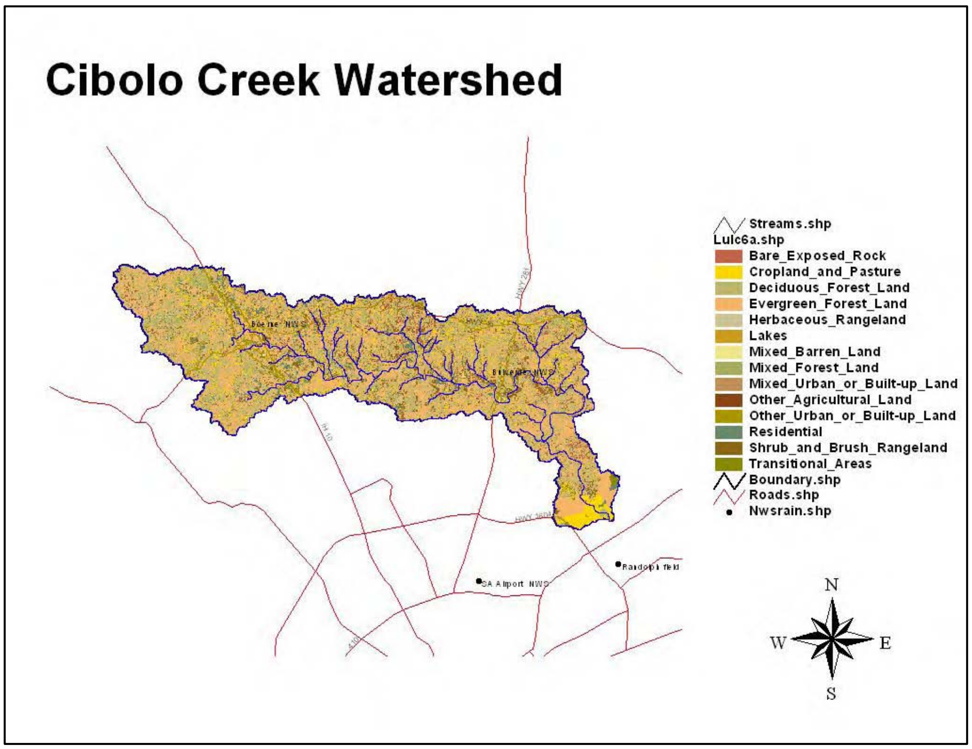

Figure 13. Land use map for Cibolo Creek Watershed.

Table 3. Estimated land use parameters.

Map ID	Description	Roughness Coefficient	Storage Capacity	Interception Coefficient	Albedo	Wilting Point
11	Residential	0.050	0.000	0.00	0.40	0.28
16	Mixed Urban or Built-up Land	0.050	0.000	0.00	0.35	0.25
17	Other Urban or Built-up Land	0.030	0.000	0.00	0.35	0.25
21	Cropland and Pasture	0.055	0.010	0.16	0.15	0.15
24	Other Agricultural Land	0.057	0.010	0.10	0.20	0.18
31	Herbaceous Rangeland	0.060	0.010	0.16	0.25	0.21
32	Shrub and Brush Rangeland	0.100	0.020	0.40	0.30	0.23
41	Deciduous Forest Land	0.066	0.040	0.18	0.10	0.10
42	Evergreen Forest Land	0.067	0.050	0.20	0.10	0.10
43	Mixed Forest Land	0.068	0.045	0.19	0.10	0.10

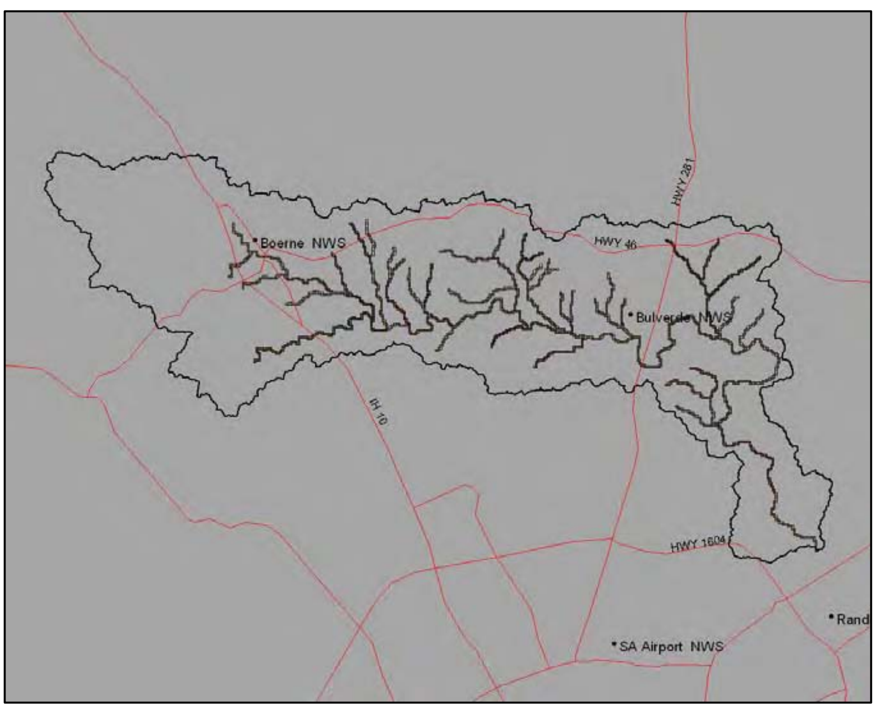

Figure 14. Rain gage locations (two gages) and stream network.

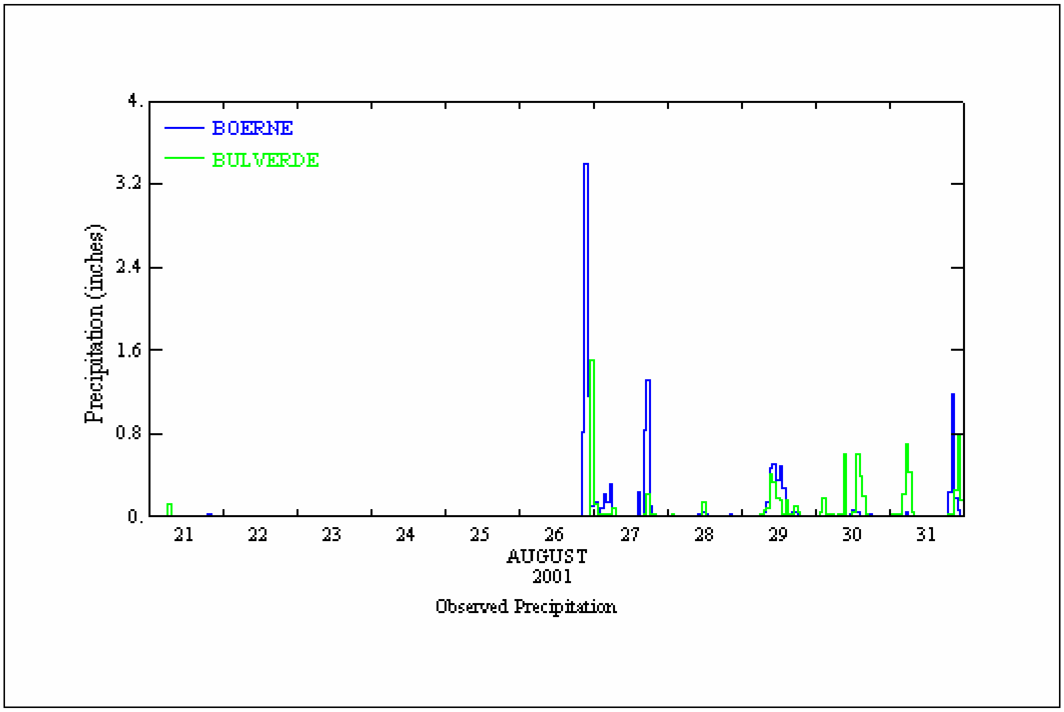

Figure 15. Precipitation depth for Boerne and Bulverde Gages.

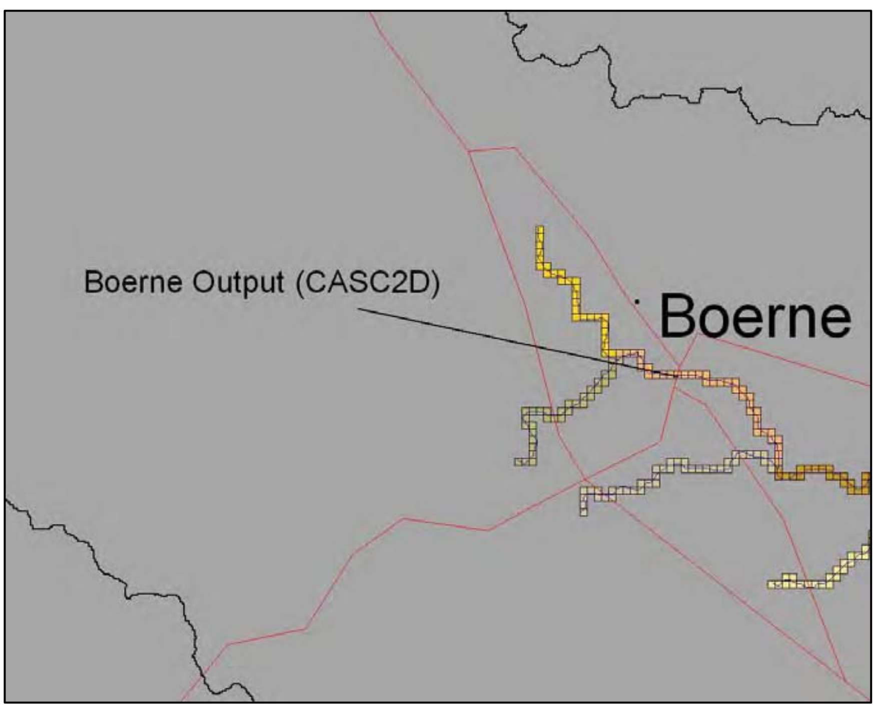

Figure 16. Flow comparison location for Boerne Gage site.

EDYS data input

The input data used for the ecological modeling effort were obtained from a variety of sources, including scientists from U. S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), and U.S. Army Corps of Engineers. Additional details on the EDYS application developed for the Cibolo Creek Watershed are described in Price et al. (2004). Specific details on input data not contained in Price et al. (2004) are described below.

Soils

Multiple soil series may occur within each vegetation community. To determine the soil series for each community, soil series maps were overlaid with vegetation maps to identify the soil series most commonly found within each community. This approach yielded nine series (Table 4). Soil characteristics for each were derived from data obtained from NRCS official soil series descriptions (http://www.statlab.iastate.edu/soils/osd) and from U.S. Soil Conservation Service classifications (USSCS 1975). Specifics for each soil series are presented in Appendix A.

Table 4. Soil series modeled in the EDYS application for Cibolo Creek Watershed.

Soil Series
Anhalt Clay
Brackett-Real Association
Brackett-Rock Outcrop-Comfort Complex
Comfort-Rock Outcrop Complex
Denton Silty Clay
Doss-Brackett Association
Eckrant-Rock Outcrop Complex
Krum Silty Clay
Lewisville Silty Clay

Plants

Sixteen native plant communities were included in the EDYS model for Cibolo Creek (Table 5). Additionally, nine land use types were identified within the model domain, for a total of 25 types being simulated.

The number of plant species included in an EDYS application is flexible and is specified in the initial parameterization. Not all species occurring in an area are included in the EDYS application for two reasons. First, very few ecological data are available for minor species. Therefore, estimates based on the major species would have to be used. This estimation increases the uncertainty associated with the EDYS simulations. Second, most of the excluded species comprise relatively small amounts of the total composition. Thus, excluding them does not significantly impact most EDYS variables.

Table 5. Vegetation communities and land use types.

Community Name
Ashe Juniper Woodland
Ashe Juniper-Live Oak Woodland (very dense cover)
Ashe Juniper-Live Oak Woodland (dense cover)
Ashe Juniper-Live Oak Woodland (moderate cover)
Ashe Juniper-Post Oak Woodland
Oak-Ashe Juniper Woodland (moderate cover)
Oak-Ashe Juniper Woodland (light cover)
Oak-Persimmon Woodland (dense cover)
Oak-Persimmon Woodland (moderate cover)
Mixed Woodland
Ashe Juniper-Persimmon Savanna
Oak Savanna
Mesquite Savanna
Shrubland
Bluestem Prairie
Shortgrass Plains
Improved Pasture
Cultivation
Urban Lawn
Urban Buildings
Roads
Rock/Bare
Water's Edge
Water
Channel

In order to account for overall community dynamics, the ecological contribution of each species not specifically included in the model must be accounted for. This is accomplished in EDYS by using composite species. In EDYS, a composite species consists of a major species plus those minor species most ecologically similar to the respective major species. Table 6 lists the composite species used in the EDYS application for Cibolo Creek.

Table 6. Plant species used in the Cibolo Creek EDYS Model.

Common Name	Scientific Name	Abbreviation
Netleaf Hackberry	*Celtis reticulata*	NlHckbry
Texas Persimmon	*Diospyros texana*	TxPrsmmn
Ashe Juniper	*Juniperus ashei*	AsheJunp
Shumard Red Oak	*Quercus shumardii*	ShRdOak
Live Oak	*Quercus virginiana*	LvOak
Cedar Elm	*Ulmus crassifolia*	CdrElm
Honey Mesquite	*Prosopis glandulosa*	Mesquite
Sotol	*Dasylirion texanum*	Sotol
Evergreen Sumac	*Rhus virens*	EvgSumac
Greenbriar	*Smilax sp.*	GrnBriar
Mountain Grape	*Vitis monticola*	MtnGrape
Annual Grass		AnnlGrs
Old-field Threeawn	*Aristida oligantha*	OfThrAn
King Ranch Bluestem	*Bothriochloa ischaemum*	KRBluStm
Silver Bluestem	*Bothriochloa saccharoides*	SiBluStm
Sideoats Grama	*Bouteloua curtipendula*	SdOtsGrm
Hairy Grama	*Bouteloua hirsuta*	HryGrm
Bermudagrass	*Cynodon dactylon*	BrmdaGrs
Texas Cupgrass	*Eriochloa sericea*	TxCupGrs
Seep Muhly	*Muhlenbergia reverchonii*	SpMuhly
Little Bluestem	*Schizachyrium scoparium*	LlBluStm
Indiangrass	*Sorghastrum nutans*	IndnGrs
Tall Dropseed	*Sporobolus asper*	TlDrpSd
Texas Wintergrass	*Stipa leucotricha*	TxWntGrs
Curly Mesquite	*Hilaria belangeri*	CrlyMsqt
Broomweed	*Amphiachyris dracunculoides*	BrmWd
Woodland Sedge	*Carex blanda*	WdSedge
Rabbit Tobacco	*Evax verna*	RbtTbaco
Prairie Bluets	*Hedyotis nigricans*	PrrBluet
Prairie Coneflower	*Ratibida columnaris*	PrCnflwr
Texas Sage	*Salvia texana*	TxSage
Doveweed	*Croton sp.*	DoveWeed

A substantial number of plant parameters are utilized in EDYS for simulating the dynamics of each species. These relate to growth, resource allocation, nutrient and water requirements, seasonality of different processes (e.g., growth, seed development, and winter die-back), root architecture, and competitive interactions. Values for each parameter were compiled from a wide range of sources in the ecological literature for each species. Typically, multiple values are available in the literature for these

parameters, so specific values were selected based on communities similar to those found in the Cibolo Creek Watershed and previous experience modeling communities in the Edwards Plateau (McLendon et al. 2001, 2002). Specific values used in this EDYS application are presented in Appendix B. Table 7 lists the initial biomasses of plant species by community and land use type.

Table 7. Initial plant biomasses by plant community and land use type.

Plant Communities									
1 - Ashe Juniper Woodland									
TxPrsmmn	79.8	AsheJunp	9746.1	Sotol	4.0	OfThrAn	0.3	KRBluStm	7.6
HryGrm	0.2	SpMuhly	0.1	TxWntGrs	1.3	CrlyMsqt	0.5	BrmWd	0.1
WdSedge	0.9	RbtTbaco	0.1	PrrBluet	0.1	PrCnflwr	0.1		
2 - Ashe Juniper-Live Oak Woodland (very dense cover)									
TxPrsmmn	119.8	AsheJunp	12000.0	LvOak	5081.3	CdrElm	264.1	Sotol	2.4
OfThrAn	0.2	SdOtsGrm	0.3	HryGrm	0.2	LlBluStm	0.1	TlDrpSd	0.6
TxWntGrs	1.3	BrmWd	0.1	WdSedge	1.5	RbtTbaco	0.1	PrrBluet	0.4
3 - Ashe Juniper-Live Oak Woodland (dense cover)									
NlHckbry	119.3	TxPrsmmn	173.0	AsheJunp	8820.0	ShRdOak	199.0	LvOak	3022.6
CdrElm	72.0	OfThrAn	0.3	SdOtsGrm	1.1	HryGrm	1.6	TxCupGrs	2.3
LlBluStm	0.1	TlDrpSd	0.3	TxWntGrs	1.8	CrlyMsqt	0.3	BrmWd	0.1
WdSedge	4.2	RbtTbaco	0.1	PrrBluet	0.2	PrCnflwr	0.1	TxSage	0.1
DoveWeed	0.5								
4 - Ashe Juniper-Live Oak Woodland (moderate cover)									
TxPrsmmn	279.5	AsheJunp	5350.8	LvOak	2963.1	CdrElm	12.0	Sotol	31.3
EvgSumac	14.0	GrnBriar	17.8	MtnGrape	10.4	OfThrAn	1.7	KRBluStm	4.5
SdOtsGrm	1.1	HryGrm	1.4	TxCupGrs	1.8	SpMuhly	0.2	LlBluStm	0.1
TlDrpSd	2.2	TxWntGrs	5.6	CrlyMsqt	2.4	BrmWd	0.2	WdSedge	1.2
RbtTbaco	0.2	PrrBluet	0.2	PrCnflwr	3.8	TxSage	1.2	DoveWeed	0.8
5 - Ashe Juniper-Post Oak Woodland									
AsheJunp	4263.0	ShRdOak	995.1	CdrElm	108.0	KRBluStm	105.3	TlDrpSd	1.4
TxWntGrs	3.2	WdSedge	1.5	PrrBluet	0.1	PrCnflwr	82.1		
6 - Oak-Ashe Juniper Woodland (moderate cover)									
NlHckbry	59.7	TxPrsmmn	20.0	AsheJunp	4557.0	LvOak	5247.9	CdrElm	660.1
Mesquite	9.5	Sotol	4.7	EvgSumac	1.9	GrnBriar	6.5	OfThrAn	2.2
KRBluStm	2.6	SiBluStm	0.4	SdOtsGrm	2.7	HryGrm	0.3	TxCupGrs	0.3
SpMuhly	0.7	LlBluStm	0.1	TlDrpSd	2.2	TxWntGrs	5.3	CrlyMsqt	0.2
BrmWd	0.1	WdSedge	3.2	RbtTbaco	0.3	PrrBluet	0.5	PrCnflwr	2.0
TxSage	0.1	DoveWeed	0.1						

(sheet 1 of 4)

Plant Communities									
7 - Oak-Ashe Juniper Woodland (light cover)									
TxPrsmmn	166.4	AsheJunp	1808.1	ShRdOak	55.3	LvOak	2403.8	CdrElm	36.0
Mesquite	210.1	Sotol	30.5	EvgSumac	12.7	GrnBriar	27.1	MtnGrape	14.6
OfThrAn	1.0	KRBluStm	31.4	SiBluStm	0.5	SdOtsGrm	0.2	HryGrm	0.1
TxCupGrs	2.2	LlBluStm	5.8	IndnGrs	0.7	TlDrpSd	0.7	TxWntGrs	2.6
CrlyMsqt	8.0	BrmWd	0.1	WdSedge	0.1	RbtTbaco	0.1	PrCnflwr	3.4
TxSage	1.6	DoveWeed	0.2						
8 - Oak-Persimmon Woodland (dense cover)									
NlHckbry	358.0	TxPrsmmn	2215.9	AsheJunp	2160.9	LvOak	9246.3	CdrElm	1176.3
Mesquite	219.6	Sotol	90.7	EvgSumac	38.0	GrnBriar	35.1	MtnGrape	20.8
OfThrAn	0.3	KRBluStm	8.8	TxCupGrs	0.3	TlDrpSd	0.2	TxWntGrs	10.3
CrlyMsqt	7.3	BrmWd	0.1	WdSedge	0.3	RbtTbaco	0.1	PrCnflwr	0.2
TxSage	0.1	DoveWeed	0.4						
9 - Oak-Persimmon Woodland (moderate cover)									
NlHckbry	59.7	TxPrsmmn	991.5	AsheJunp	86.8	ShRdOak	1194.2	LvOak	3581.9
CdrElm	156.0	Sotol	6.2	EvgSumac	16.5	GrnBriar	3.7	MtnGrape	52.1
OfThrAn	0.6	KRBluStm	29.1	SiBluStm	3.6	SdOtsGrm	2.6	HryGrm	1.3
TxCupGrs	0.7	LlBluStm	3.3	TlDrpSd	1.2	TxWntGrs	8.6	CrlyMsqt	1.6
BrmWd	0.1	WdSedge	1.8	RbtTbaco	0.2	PrrBluet	0.1	PrCnflwr	4.5
DoveWeed	0.1								
10 - Mixed Woodland									
NlHckbry	5154.7	TxPrsmmn	212.9	AsheJunp	3719.1	ShRdOak	1824.4	LvOak	3724.7
CdrElm	900.2	Sotol	2.6	EvgSumac	25.3	GrnBriar	18.4	MtnGrape	125.0
OfThrAn	0.1	KRBluStm	3.3	SdOtsGrm	0.1	HryGrm	0.3	TxCupGrs	0.6
LlBluStm	1.8	TlDrpSd	1.0	TxWntGrs	0.1	BrmWd	0.1	WdSedge	1.6
PrrBluet	0.8	PrCnflwr	0.1	DoveWeed	0.3				
11 - Ashe Juniper-Persimmon Savanna									
TxPrsmmn	443.5	AsheJunp	852.6	CdrElm	24.0	Sotol	29.0	EvgSumac	1.3
GrnBriar	1.8	MtnGrape	4.2	OfThrAn	0.9	KRBluStm	0.1	SiBluStm	1.2
SdOtsGrm	1.9	HryGrm	0.3	BrmdaGrs	0.3	TxCupGrs	0.6	LlBluStm	0.3
TlDrpSd	0.1	TxWntGrs	0.6	CrlyMsqt	0.7	BrmWd	0.1	WdSedge	0.3
RbtTbaco	0.1	PrrBluet	9.4	PrCnflwr	152.7	TxSage	0.3	DoveWeed	0.1
12 - Oak Savanna									
TxPrsmmn	33.3	AsheJunp	147.0	LvOak	1106.7	Sotol	5.5	OfThrAn	0.4
KRBluStm	42.2	SiBluStm	0.1	SdOtsGrm	2.2	HryGrm	2.1	TxCupGrs	2.0
LlBluStm	7.2	IndnGrs	1.9	TlDrpSd	6.0	CrlyMsqt	3.9	BrmWd	0.1
WdSedge	2.2	RbtTbaco	3.9	PrrBluet	0.6	PrCnflwr	4.7	TxSage	0.5
DoveWeed	0.2								

(sheet 2 of 4)

Plant Communities									
13 - Mesquite Savanna									
Mesquite	2912.4	Sotol	74.3	OfThrAn	1.3	SiBluStm	21.3	LlBluStm	1.8
TxWntGrs	128.8	CrlyMsqt	3.8	BrmWd	0.1	PrCnflwr	25.6	TxSage	0.2
DoveWeed	0.4								
14 – Shrubland									
AsheJunp	147.0	LvOak	119.0	Sotol	203.2	MtnGrape	52.1	OfThrAn	0.8
SdOtsGrm	4.3	HryGrm	2.9	LlBluStm	9.1	TlDrpSd	1.3	BrmWd	0.6
WdSedge	1.4	RbtTbaco	0.2	PrCnflwr	33.4	TxSage	0.1	DoveWeed	0.8
15 - Bluestem Prairie									
LvOak	95.2	CdrElm	24.0	Mesquite	143.2	Sotol	9.4	OfThrAn	1.9
KRBluStm	137.2	SiBluStm	7.0	SdOtsGrm	33.8	HryGrm	2.8	TxCupGrs	1.2
LlBluStm	13.5	TlDrpSd	1.8	TxWntGrs	0.6	CrlyMsqt	0.8	BrmWd	0.1
WdSedge	0.1	RbtTbaco	0.1	PrrBluet	1.4	PrCnflwr	6.7	TxSage	0.5
DoveWeed	0.1								
16 - Shortgrass Plains									
OfThrAn	2.2	KRBluStm	1.1	SdOtsGrm	1.3	HryGrm	7.4	TxCupGrs	1.1
LlBluStm	7.1	TlDrpSd	0.1	TxWntGrs	10.6	CrlyMsqt	13.6	BrmWd	0.3
WdSedge	0.1	RbtTbaco	1.9	PrrBluet	0.8	PrCnflwr	12.8	TxSage	0.5
DoveWeed	0.4								
17 – Improved Pasture									
KRBluStm	28.9	BrmdaGrs	132.0	PrCnflwr	2.1	DoveWeed	1.5		
18 – Cultivation									
No Initial Biomass									
19 – Urban Lawn									
TxPrsmmn	33.3	LvOak	1190.0	Mesquite	32.4	Sotol	0.8	BrmdaGrs	132.0
PrCnflwr	0.2								
20 – Urban Building									
No Initial Biomass									
21 – Roads									
GrnBriar	6.9	OfThrAn	7.0	KRBluStm	92.4	SiBluStm	1.9	SdOtsGrm	1.8
HryGrm	3.4	BrmdaGrs	46.9	TxCupGrs	1.6	LlBluStm	1.0	TxWntGrs	49.3
CrlyMsqt	18.6	BrmWd	3.4	RbtTbaco	2.8	PrrBluet	1.8	PrCnflwr	4.2
TxSage	1.6	DoveWeed	3.0						
22 – Rock/Bare									
TxPrsmmn	33.3	AsheJunp	147.0	LvOak	59.5	Mesquite	47.7	Sotol	7.8
EvgSumac	6.3	OfThrAn	0.1	SiBluStm	0.1	SdOtsGrm	0.1	HryGrm	0.1
BrmdaGrs	0.1	LlBluStm	0.1	IndnGrs	0.1	BrmWd	0.1	RbtTbaco	0.1
PrCnflwr	0.1	TxSage	0.1						

(sheet 3 of 4)

Plant Communities									
23 – Water's Edge									
NIHckbry	119.3	CdrElm	120.0	GrnBriar	29.6	MtnGrape	20.8	KRBluStm	77.1
SiBluStm	49.4	BrmdaGrs	78.2	TxCupGrs	85.3	SpMuhly	46.3	LIBluStm	25.6
IndnGrs	97.8	BrmWd	4.5	PrrBluet	24.4	PrCnflwr	27.7	DoveWeed	3.9
24 – Water									
No Initial Biomass									
25 – Channel									
No Initial Biomass									

(sheet 4 of 4)

Hydrologic model output

Figures 17 and 18 show observed versus simulated flows for the Boerne and Selma Gages, respectively. Figure 19 demonstrates the 2-D output capacity of the modeling system.

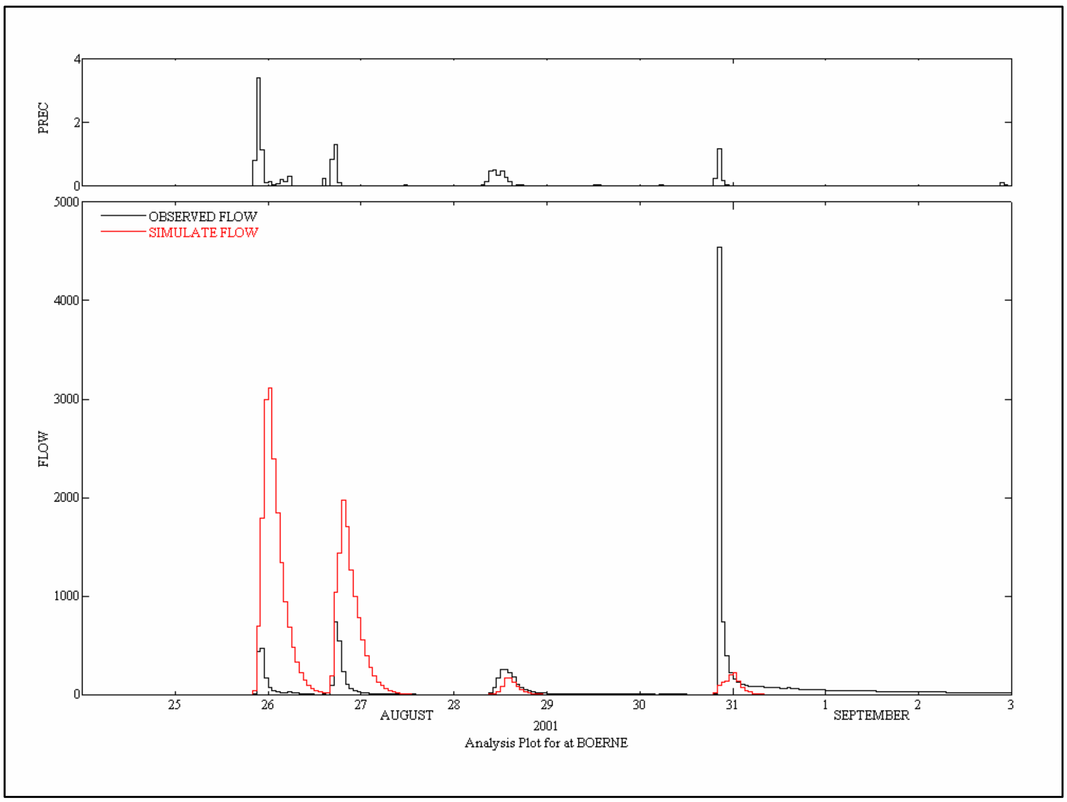

Figure 17. Flow (cfs) output at Boerne Gage.

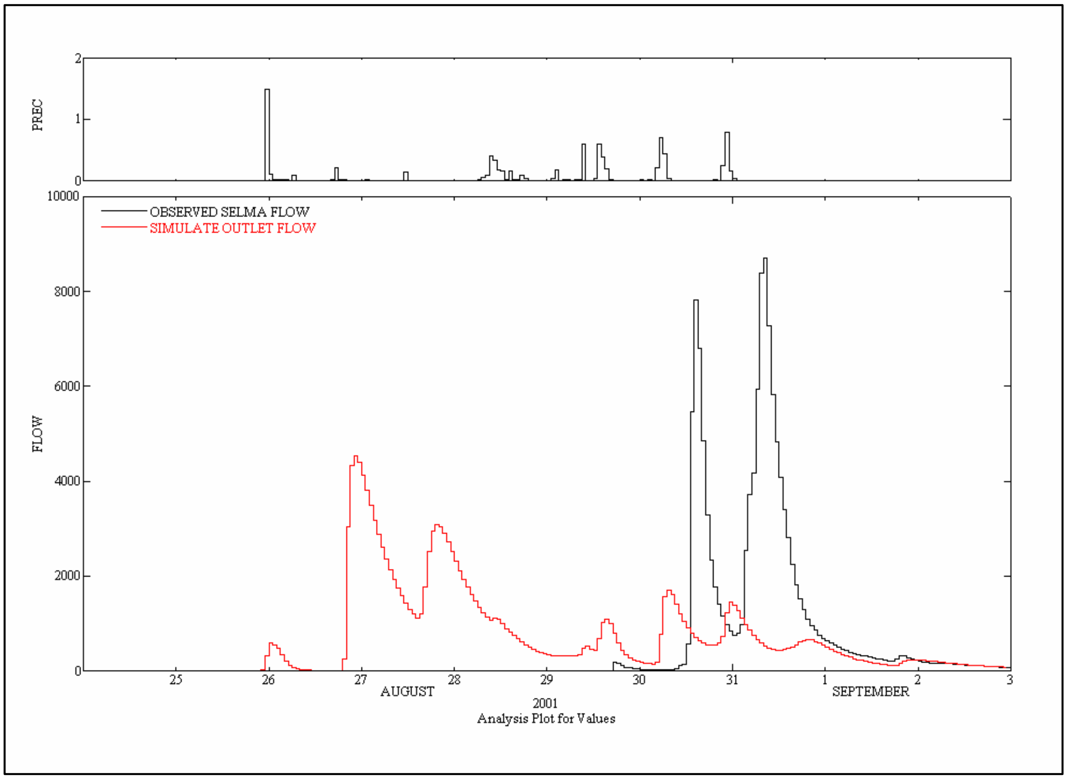

Figure 18. Flow (cfs) Output at Selma Gage (Watershed Outlet).

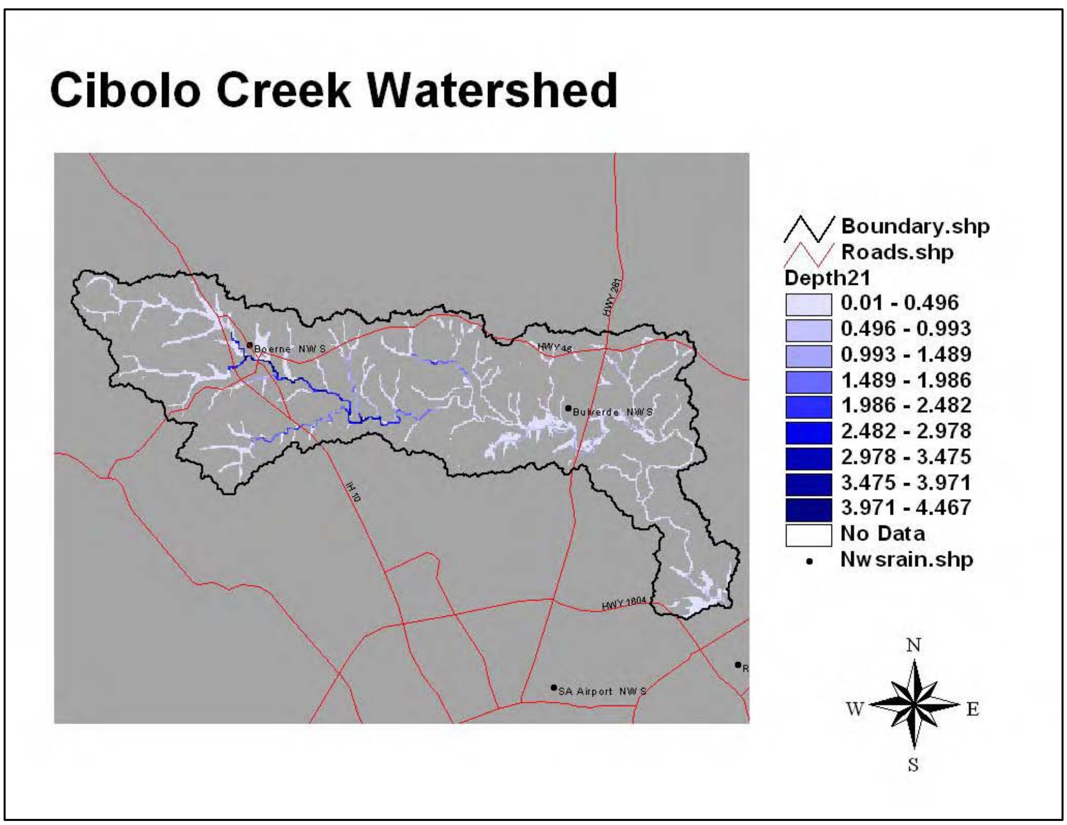

Figure 19. Surface and channel depths (m) at 8/27/01 0:00.

EDYS model output

The precipitation events handled by GSSHA all occurred within August of 2001. Therefore, any improvements in EDYS model performance with the linkage will only be seen after August. Table 8 illustrates differences in total soil moisture on 1 September 2001 between the linked run and an unlinked EDYS run for the same time period. Note the total soil moisture for the linked run is higher than the EDYS-only run. This would be expected due to the more sophisticated infiltration/percolation algorithm used by GSSHA, allowing greater retention times in the profile prior to percolating below the rooting zone of the plants. As a result, plant growth is slightly increased in the month following the precipitation events modeled by GSSHA (Table 9). For most communities, the increase is small (< 1.0 percent), but the increased production in the grassland communities is higher (from 3 to 23 percent). This greater increase arises from the ability of grasses and forbs to respond more quickly to increased moisture conditions, as compared to trees and shrubs.

Table 8. Total soil moisture on 1 September (mm).

Community Type	EDYS Only	EDYS-GSSHA Linked
Ashe Juniper Woodland	359.4	360.3
Ashe Juniper-Live Oak Woodland (very dense cover)	72.9	74.3
Ashe Juniper-Live Oak Woodland (dense cover)	182.7	183.7
Ashe Juniper-Live Oak Woodland (moderate cover)	266.3	271.9
Ashe Juniper-Post Oak Woodland	235.3	259.6
Oak-Ashe Juniper Woodland (moderate cover)	75.6	82.1
Oak-Ashe Juniper Woodland (light cover)	457.6	486.1
Oak-Persimmon Woodland (dense cover)	77.4	101.1
Oak-Persimmon Woodland (moderate cover)	486.3	495.0
Mixed Woodland	80.1	91.4
Ashe Juniper-Persimmon Savanna	367.5	518.5
Oak Savanna	571.9	575.7
Mesquite Savanna	223.7	337.2
Shrubland	367.5	422.9
Bluestem Prairie	227.8	332.6
Shortgrass Plains	513.7	604.3
Improved Pasture	499.3	559.3
Cultivation	330.9	354.8
Urban Lawn	408.4	440.6
Water's Edge	394.2	438.3

Table 9. Total aboveground biomass on 30 September (g/m²).

Community Type	EDYS Only	EDYS-GSSHA Linked
Ashe Juniper Woodland	9714.22	9790.44
Ashe Juniper-Live Oak Woodland (very dense cover)	16624.62	16650.66
Ashe Juniper-Live Oak Woodland (dense cover)	12013.50	12063.44
Ashe Juniper-Live Oak Woodland (moderate cover)	8681.51	8734.18
Ashe Juniper-Post Oak Woodland	5820.61	5918.95
Oak-Ashe Juniper Woodland (moderate cover)	10297.90	10336.16
Oak-Ashe Juniper Woodland (light cover)	4876.58	4877.33
Oak-Persimmon Woodland (dense cover)	15223.35	15246.38
Oak-Persimmon Woodland (moderate cover)	6248.30	6248.34
Mixed Woodland	15563.26	15598.76
Ashe Juniper-Persimmon Savanna	1911.52	1972.53
Oak Savanna	1434.29	1434.27
Mesquite Savanna	3313.95	3386.67
Shrubland	844.07	854.19
Bluestem Prairie	749.86	922.13
Shortgrass Plains	328.79	339.77
Improved Pasture	652.04	709.30
Cultivation	12.26	19.58
Urban Lawn	1697.10	1697.06
Water's Edge	1101.03	1108.08

5 Conclusions and Recommendations

The purpose of this development activity was to work out the mechanism by which GSSHA and EDYS could manually exchange data and to evaluate the need for more complex data exchanges between the two modeling systems. As has been mentioned previously, the only data exchanged between the two models was soil moisture data. It is anticipated that in the future, data layers such as roughness, hydraulic conductivity, nutrient masses, etc. can be exchanged in order to further enhance the nutrient sub-modules in addition to allowing the user to model dynamic land use changes due to either man-made scenarios (i.e., urban growth or military training) or due to natural scenarios (i.e., forest fires). As the data exchanges become more complex, detailed long-term simulations will be achievable whereby small restoration features can be evaluated within the context of the whole system.

Conclusions drawn during this study seem to indicate that more work is needed in calibrating the hydraulics and hydrology modules in order to better compare to the Boerne and Selma Gages. As part of this investigation, better rainfall estimates need to be made and a geologic investigation needs to be done such that channel and overland transmission losses can be better estimated.

Finally, it is the recommendation of the authors that further enhancements to the manual linkage can and should proceed in order to provide the nutrient sub-modules with the ability to have plant uptake and biomass loading. In addition, the enhancements will allow for more accurate water budget computations and for dynamic soil and land use parameter estimations over long-term simulation periods.

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Appendix A: Soil Series Characteristics

Anhalt Clay

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m^2)	Nitrogen (g/m^2)
Ap	25	23.80	40.40	53.20	1625.00	131.30
Ap	25	23.80	40.40	53.20	1397.50	112.92
Ap	25	23.80	40.40	53.20	1235.00	99.79
A1	25	23.80	40.40	53.20	1105.00	89.28
A1	25	23.80	40.40	53.20	975.00	78.78
A1	50	23.80	40.40	53.20	1755.00	141.80
Bss1	150	39.00	52.80	56.00	4500.00	363.60
Bss1	150	39.00	52.80	56.00	3750.00	303.00
Bss1	125	39.00	52.80	56.00	1562.50	126.25
Bss1	125	39.00	52.80	56.00	1406.25	113.63
Cr	75	0.80	1.10	1.10	0.34	0.03
Cr	75	0.80	1.10	1.10	0.17	0.01
Cr	125	0.80	1.10	1.10	0.28	0.02

Brackett-Real Association

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m^2)	Nitrogen (g/m^2)
A	25	19.47	30.37	49.49	840.00	84.01
A	25	19.47	30.37	49.49	805.00	80.51
A	50	19.47	30.37	49.49	1190.00	119.01
A	50	19.47	30.37	49.49	1120.00	112.01
Bw	50	12.52	26.25	46.90	1033.00	103.32
Bw	50	12.52	26.25	46.90	962.00	96.20
Bw	50	12.52	26.25	46.90	819.00	81.95
Bw	50	12.52	26.25	46.90	748.00	74.82
C	100	25.40	39.82	52.62	1425.00	142.51
C	100	25.40	39.82	52.62	1275.00	127.51
C	300	25.40	39.82	52.62	3375.00	337.51
C	300	25.40	39.82	52.62	2925.00	292.51
C	400	25.40	39.82	52.62	3300.00	330.01

Brackett-Rock Outcrop-Comfort Complex

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
A	25	14.77	26.65	47.63	840.00	84.01
A	25	14.77	26.65	47.63	805.00	80.51
A	50	14.77	26.65	47.63	1190.00	119.01
A	50	14.77	26.65	47.63	1120.00	112.01
Bw	50	16.95	29.65	49.15	1033.00	103.32
Bw	50	16.95	29.65	49.15	962.00	96.20
Bw	50	16.95	29.65	49.15	819.00	81.95
Bw	50	16.95	29.65	49.15	748.00	74.82
Cr	100	17.06	28.45	48.64	1354.00	135.39
Cr	100	17.06	28.45	48.64	1211.00	121.14
Cr	200	17.06	28.45	48.64	2138.00	213.76
Cr	350	17.06	28.45	48.64	3242.00	324.20
Cr	450	17.06	28.45	48.64	3527.00	352.70

Comfort-Rock Outcrop Complex

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
A	25	19.46	31.29	49.86	2188.00	196.89
A	25	19.46	31.29	49.86	2031.00	182.82
A	50	19.46	31.29	49.86	3438.00	309.39
A	50	19.46	31.29	49.86	3125.00	281.26
Bt	25	24.06	31.07	50.30	1530.00	137.71
Bt	50	24.06	31.07	50.30	2933.00	263.94
Bt	50	24.06	31.07	50.30	2805.00	252.46
Bt	50	24.06	31.07	50.30	2678.00	240.99
R	25	1.24	1.31	1.50	0	0.04
R	25	1.24	1.31	1.50	0	0.04
R	25	1.00	1.00	1.00	0	0.01
R	25	1.00	1.00	1.00	0	0.01
R	25	1.00	1.00	1.00	0	0.01

Denton Silty Clay

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
Ap	25	19.42	36.12	51.81	938.00	93.76
Ap	50	19.42	36.12	51.81	1750.00	175.01
Ap	50	19.42	36.12	51.81	1563.00	156.26
A	75	25.66	41.33	53.20	2063.00	206.26
A	75	25.66	41.33	53.20	1875.00	187.51
Bw	750	25.51	40.44	52.84	1877.00	187.66
Bw	125	25.51	40.44	52.84	2606.00	260.64
Bw	125	25.51	40.44	52.84	2085.00	208.51
2Bk	125	20.54	34.51	51.03	1906.00	190.64
2Bk	125	20.54	34.51	51.03	1334.00	133.45
2CBk	50	19.45	32.63	50.36	381.00	38.14
2CBk	75	19.45	32.63	50.36	229.00	22.89
2R	525	1.00	1.00	1.00	0	0.01

Doss-Brackett Association

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
A	25	19.47	30.37	49.49	840.00	84.01
A	25	19.47	30.37	49.49	805.00	80.51
A	50	19.47	30.37	49.49	1190.00	119.01
A	50	19.47	30.37	49.49	1120.00	112.01
Bk	50	14.62	27.80	48.14	1033.00	103.32
Bk	75	14.62	27.80	48.14	1443.00	144.29
Bk	75	14.62	27.80	48.14	1229.00	122.92
Cr	100	22.18	35.27	51.25	825.00	82.51
Cr	200	22.18	35.27	51.25	2850.00	285.01
Cr	200	22.18	35.27	51.25	2550.00	255.01
Cr	200	22.18	35.27	51.25	2250.00	225.01
Cr	250	16.84	30.89	49.66	2438.00	243.76
Cr	250	16.84	30.89	49.66	2063.00	206.26

Eckrant-Rock Outcrop Complex

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
A1	25	30.42	41.56	52.87	3988.00	279.14
A1	50	30.42	41.56	52.87	7250.00	507.51
A1	50	30.42	41.56	52.87	6525.00	456.76
A1	50	30.42	41.56	52.87	5800.00	406.01
A1	75	30.42	41.56	52.87	7613.00	532.89
A2	75	21.94	32.56	50.31	6638.00	464.64
A2	75	21.94	32.56	50.31	5531.00	387.20
A2	100	21.94	32.56	50.31	5900.00	413.01
A2	100	21.94	32.56	50.31	4425.00	309.76
A2	100	21.94	32.56	50.31	2950.00	206.51
R	125	1.22	1.33	1.50	2.00	0.14
R	250	1.00	1.00	1.00	0	0.01
R	250	1.00	1.00	1.00	0	0.01

Krum Silty Clay

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m²)	Nitrogen (g/m²)
Ap	25	23.80	40.40	53.20	1087.50	87.87
Ap	50	23.80	40.40	53.20	2030.00	164.02
Ap	75	23.80	40.40	53.20	2610.00	210.89
A	75	23.80	40.40	53.20	2175.00	175.74
A	75	23.80	40.40	53.20	1957.50	158.17
A	100	23.80	40.40	53.20	2320.00	187.46
Bw	175	33.40	46.50	54.10	3128.13	252.75
Bw	200	33.40	46.50	54.10	2750.00	222.20
Bw	200	33.40	46.50	54.10	2475.00	199.98
Bw	200	33.40	46.50	54.10	2200.00	177.76
Bk1	125	28.30	43.80	53.80	1246.88	100.75
Bk1	125	28.30	43.80	53.80	1068.75	86.36
Bk2	125	28.30	43.80	53.80	890.63	71.96

Lewisville Silty Clay

Layer Name	Depth (mm)	Wilting Point (%)	Field Capacity (%)	Saturation (%)	Organic Matter (g/m^2)	Nitrogen (g/m^2)
Ap	25	25.80	42.50	53.90	975.00	78.78
Ap	50	25.80	42.50	53.90	1820.00	147.06
Ap	50	25.80	42.50	53.90	1625.00	131.30
A	50	25.80	42.50	53.90	1495.00	120.80
A	50	25.80	42.50	53.90	1300.00	105.04
A	100	25.80	42.50	53.90	2340.00	189.07
A	100	25.80	42.50	53.90	1950.00	157.56
Bk1	125	25.70	41.30	53.20	2153.00	173.97
Bk1	175	25.70	41.30	53.20	2551.00	206.09
Bk1	175	25.70	41.30	53.20	2319.00	187.36
Bk2	125	19.40	36.50	52.00	1400.00	113.12
Bk2	250	19.40	36.50	52.00	2100.00	169.68
Bk2	250	19.40	36.50	52.00	1400.00	113.12

Appendix B: Plant Parameters

Table B1. Mature allocation matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NIHckbry	0.20	0.10	0.50	0.15	0.05	0.00
TxPrsmmn	0.22	0.11	0.45	0.15	0.07	0.00
AsheJunp	0.25	0.09	0.34	0.21	0.11	0.00
ShRdOak	0.26	0.14	0.31	0.25	0.04	0.00
LvOak	0.25	0.13	0.31	0.27	0.04	0.00
CdrElm	0.18	0.09	0.48	0.20	0.05	0.00
Mesquite	0.32	0.15	0.28	0.19	0.06	0.00
Sotol	0.44	0.29	0.08	0.03	0.16	0.00
EvgSumac	0.60	0.12	0.09	0.12	0.07	0.00
GrnBriar	0.25	0.25	0.25	0.08	0.16	0.00
MtnGrape	0.60	0.12	0.20	0.02	0.06	0.00
AnnlGrs	0.06	0.32	0.20	0.22	0.20	0.00
OfThrAn	0.09	0.33	0.10	0.15	0.33	0.00
KRBluStm	0.24	0.36	0.15	0.15	0.10	0.00
SiBluStm	0.22	0.33	0.16	0.17	0.12	0.00
SdOtsGrm	0.19	0.30	0.14	0.13	0.14	0.00
HryGrm	0.14	0.56	0.10	0.08	0.12	0.00
BrmdaGrs	0.31	0.43	0.04	0.14	0.08	0.00
TxCupGrs	0.06	0.32	0.20	0.22	0.20	0.00
SpMuhly	0.10	0.46	0.15	0.10	0.19	0.00
LIBluStm	0.22	0.33	0.10	0.16	0.19	0.00
IndnGrs	0.25	0.37	0.13	0.13	0.12	0.00
TlDrpSd	0.25	0.38	0.08	0.15	0.14	0.00
TxWntGrs	0.12	0.44	0.14	0.12	0.18	0.00
CrlyMsqt	0.14	0.56	0.08	0.06	0.16	0.00
BrmWd	0.15	0.16	0.23	0.20	0.26	0.00
WdSedge	0.13	0.50	0.15	0.06	0.16	0.00
RbtTbaco	0.33	0.33	0.10	0.07	0.17	0.00
PrrBluet	0.33	0.33	0.12	0.06	0.16	0.00
PrCnflwr	0.33	0.33	0.13	0.04	0.17	0.00
TxSage	0.30	0.30	0.13	0.07	0.20	0.00
DoveWeed	0.20	0.05	0.19	0.09	0.47	0.00

Note: Allocation is the proportion of initial biomass that is allocated to different plant components.

CRoot: Coarse Root

FRoot: Fine Root

Table B2. Current allocation matrix.

Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NlHckbry	Jan	0.13	0.37	0.20	0.14	0.16	0.00
	Feb	0.13	0.37	0.20	0.14	0.16	0.00
	Mar	0.13	0.37	0.20	0.14	0.16	0.00
	Apr	0.13	0.37	0.20	0.14	0.16	0.00
	May	0.13	0.37	0.20	0.14	0.16	0.00
	Jun	0.13	0.37	0.20	0.14	0.16	0.00
	Jul	0.13	0.37	0.20	0.14	0.16	0.00
	Aug	0.13	0.37	0.20	0.14	0.16	0.00
	Sep	0.13	0.37	0.20	0.14	0.16	0.00
	Oct	0.13	0.37	0.20	0.14	0.16	0.00
	Nov	0.13	0.37	0.20	0.14	0.16	0.00
	Dec	0.13	0.37	0.20	0.14	0.16	0.00
TxPrsmmn	Jan	0.14	0.38	0.18	0.14	0.16	0.00
	Feb	0.14	0.38	0.18	0.14	0.16	0.00
	Mar	0.14	0.38	0.18	0.14	0.16	0.00
	Apr	0.14	0.38	0.18	0.14	0.16	0.00
	May	0.14	0.38	0.18	0.14	0.16	0.00
	Jun	0.14	0.38	0.18	0.14	0.16	0.00
	Jul	0.14	0.38	0.18	0.14	0.16	0.00
	Aug	0.14	0.38	0.18	0.14	0.16	0.00
	Sep	0.14	0.38	0.18	0.14	0.16	0.00
	Oct	0.14	0.38	0.18	0.14	0.16	0.00
	Nov	0.14	0.38	0.18	0.14	0.16	0.00
	Dec	0.14	0.38	0.18	0.14	0.16	0.00
AsheJunp	Jan	0.11	0.32	0.19	0.19	0.19	0.00
	Feb	0.11	0.32	0.19	0.19	0.19	0.00
	Mar	0.11	0.32	0.19	0.19	0.19	0.00
	Apr	0.11	0.32	0.19	0.19	0.19	0.00
	May	0.11	0.32	0.19	0.19	0.19	0.00
	Jun	0.11	0.32	0.19	0.19	0.19	0.00
	Jul	0.11	0.32	0.19	0.19	0.19	0.00
	Aug	0.11	0.32	0.19	0.19	0.19	0.00
	Sep	0.11	0.32	0.19	0.19	0.19	0.00
	Oct	0.11	0.32	0.19	0.19	0.19	0.00
	Nov	0.11	0.32	0.19	0.19	0.19	0.00
	Dec	0.11	0.32	0.19	0.19	0.19	0.00
ShRdOak	Jan	0.14	0.38	0.21	0.13	0.14	0.00
	Feb	0.14	0.38	0.21	0.13	0.14	0.00
	Mar	0.14	0.38	0.21	0.13	0.14	0.00
	Apr	0.14	0.38	0.21	0.13	0.14	0.00
	May	0.14	0.38	0.21	0.13	0.14	0.00
	Jun	0.14	0.38	0.21	0.13	0.14	0.00
	Jul	0.14	0.38	0.21	0.13	0.14	0.00

(sheet 1 of 9)

Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
ShRdOak (cont)	Aug	0.14	0.38	0.21	0.13	0.14	0.00
	Sep	0.14	0.38	0.21	0.13	0.14	0.00
	Oct	0.14	0.38	0.21	0.13	0.14	0.00
	Nov	0.14	0.38	0.21	0.13	0.14	0.00
	Dec	0.14	0.38	0.21	0.13	0.14	0.00
LvOak	Jan	0.14	0.39	0.20	0.17	0.10	0.00
	Feb	0.14	0.39	0.20	0.17	0.10	0.00
	Mar	0.14	0.39	0.20	0.17	0.10	0.00
	Apr	0.14	0.39	0.20	0.17	0.10	0.00
	May	0.14	0.39	0.20	0.17	0.10	0.00
	Jun	0.14	0.39	0.20	0.17	0.10	0.00
	Jul	0.14	0.39	0.20	0.17	0.10	0.00
	Aug	0.14	0.39	0.20	0.17	0.10	0.00
	Sep	0.14	0.39	0.20	0.17	0.10	0.00
	Oct	0.14	0.39	0.20	0.17	0.10	0.00
	Nov	0.14	0.39	0.20	0.17	0.10	0.00
	Dec	0.14	0.39	0.20	0.17	0.10	0.00
CdrElm	Jan	0.13	0.38	0.21	0.13	0.15	0.00
	Feb	0.13	0.38	0.21	0.13	0.15	0.00
	Mar	0.13	0.38	0.21	0.13	0.15	0.00
	Apr	0.13	0.38	0.21	0.13	0.15	0.00
	May	0.13	0.38	0.21	0.13	0.15	0.00
	Jun	0.13	0.38	0.21	0.13	0.15	0.00
	Jul	0.13	0.38	0.21	0.13	0.15	0.00
	Aug	0.13	0.38	0.21	0.13	0.15	0.00
	Sep	0.13	0.38	0.21	0.13	0.15	0.00
	Oct	0.13	0.38	0.21	0.13	0.15	0.00
	Nov	0.13	0.38	0.21	0.13	0.15	0.00
	Dec	0.13	0.38	0.21	0.13	0.15	0.00
Mesquite	Jan	0.14	0.40	0.10	0.15	0.21	0.00
	Feb	0.14	0.40	0.10	0.15	0.21	0.00
	Mar	0.14	0.40	0.10	0.15	0.21	0.00
	Apr	0.14	0.40	0.10	0.15	0.21	0.00
	May	0.14	0.40	0.10	0.15	0.21	0.00
	Jun	0.14	0.40	0.10	0.15	0.21	0.00
	Jul	0.14	0.40	0.10	0.15	0.21	0.00
	Aug	0.14	0.40	0.10	0.15	0.21	0.00
	Sep	0.14	0.40	0.10	0.15	0.21	0.00
	Oct	0.14	0.40	0.10	0.15	0.21	0.00
	Nov	0.14	0.40	0.10	0.15	0.21	0.00
	Dec	0.14	0.40	0.10	0.15	0.21	0.00
Sotol	Jan	0.10	0.30	0.20	0.01	0.39	0.00
	Feb	0.10	0.30	0.20	0.01	0.39	0.00
	Mar	0.10	0.30	0.20	0.01	0.39	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Sotol (cont)	Apr	0.10	0.30	0.20	0.01	0.39	0.00
	May	0.10	0.30	0.20	0.01	0.39	0.00
	Jun	0.10	0.30	0.20	0.01	0.39	0.00
	Jul	0.10	0.30	0.20	0.01	0.39	0.00
	Aug	0.10	0.30	0.20	0.01	0.39	0.00
	Sep	0.10	0.30	0.20	0.01	0.39	0.00
	Oct	0.10	0.30	0.20	0.01	0.39	0.00
	Nov	0.10	0.30	0.20	0.01	0.39	0.00
	Dec	0.10	0.30	0.20	0.01	0.39	0.00
EvgSumac	Jan	0.10	0.28	0.18	0.24	0.20	0.00
	Feb	0.10	0.28	0.18	0.24	0.20	0.00
	Mar	0.10	0.28	0.18	0.24	0.20	0.00
	Apr	0.10	0.28	0.18	0.24	0.20	0.00
	May	0.10	0.28	0.18	0.24	0.20	0.00
	Jun	0.10	0.28	0.18	0.24	0.20	0.00
	Jul	0.10	0.28	0.18	0.24	0.20	0.00
	Aug	0.10	0.28	0.18	0.24	0.20	0.00
	Sep	0.10	0.28	0.18	0.24	0.20	0.00
	Oct	0.10	0.28	0.18	0.24	0.20	0.00
	Nov	0.10	0.28	0.18	0.24	0.20	0.00
	Dec	0.10	0.28	0.18	0.24	0.20	0.00
GrnBriar	Jan	0.15	0.15	0.10	0.30	0.30	0.00
	Feb	0.15	0.15	0.10	0.30	0.30	0.00
	Mar	0.15	0.15	0.10	0.30	0.30	0.00
	Apr	0.15	0.15	0.10	0.30	0.30	0.00
	May	0.15	0.15	0.10	0.30	0.30	0.00
	Jun	0.15	0.15	0.10	0.30	0.30	0.00
	Jul	0.15	0.15	0.10	0.30	0.30	0.00
	Aug	0.15	0.15	0.10	0.30	0.30	0.00
	Sep	0.15	0.15	0.10	0.30	0.30	0.00
	Oct	0.15	0.15	0.10	0.30	0.30	0.00
	Nov	0.15	0.15	0.10	0.30	0.30	0.00
	Dec	0.15	0.15	0.10	0.30	0.30	0.00
MtnGrape	Jan	0.10	0.28	0.22	0.10	0.30	0.00
	Feb	0.10	0.28	0.22	0.10	0.30	0.00
	Mar	0.10	0.28	0.22	0.10	0.30	0.00
	Apr	0.10	0.28	0.22	0.10	0.30	0.00
	May	0.10	0.28	0.22	0.10	0.30	0.00
	Jun	0.10	0.28	0.22	0.10	0.30	0.00
	Jul	0.10	0.28	0.22	0.10	0.30	0.00
	Aug	0.10	0.28	0.22	0.10	0.30	0.00
	Sep	0.10	0.28	0.22	0.10	0.30	0.00
	Oct	0.10	0.28	0.22	0.10	0.30	0.00
	Nov	0.10	0.28	0.22	0.10	0.30	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
MtnGrape (cont)	Dec	0.10	0.28	0.22	0.10	0.30	0.00
AnnlGrs	Jan	0.05	0.37	0.13	0.20	0.25	0.00
	Feb	0.05	0.37	0.13	0.20	0.25	0.00
	Mar	0.05	0.37	0.13	0.20	0.25	0.00
	Apr	0.05	0.37	0.13	0.20	0.25	0.00
	May	0.05	0.37	0.13	0.20	0.25	0.00
	Jun	0.05	0.37	0.13	0.20	0.25	0.00
	Jul	0.05	0.37	0.13	0.20	0.25	0.00
	Aug	0.05	0.37	0.13	0.20	0.25	0.00
	Sep	0.05	0.37	0.13	0.20	0.25	0.00
	Oct	0.05	0.37	0.13	0.20	0.25	0.00
	Nov	0.05	0.37	0.13	0.20	0.25	0.00
	Dec	0.05	0.37	0.13	0.20	0.25	0.00
OfThrAn	Jan	0.08	0.34	0.10	0.15	0.33	0.00
	Feb	0.08	0.34	0.10	0.15	0.33	0.00
	Mar	0.08	0.34	0.10	0.15	0.33	0.00
	Apr	0.08	0.34	0.10	0.15	0.33	0.00
	May	0.08	0.34	0.10	0.15	0.33	0.00
	Jun	0.08	0.34	0.10	0.15	0.33	0.00
	Jul	0.08	0.34	0.10	0.15	0.33	0.00
	Aug	0.08	0.34	0.10	0.15	0.33	0.00
	Sep	0.08	0.34	0.10	0.15	0.33	0.00
	Oct	0.08	0.34	0.10	0.15	0.33	0.00
	Nov	0.08	0.34	0.10	0.15	0.33	0.00
	Dec	0.08	0.34	0.10	0.15	0.33	0.00
KRBluStm	Jan	0.08	0.35	0.14	0.17	0.28	0.00
	Feb	0.08	0.35	0.14	0.17	0.28	0.00
	Mar	0.08	0.35	0.14	0.17	0.28	0.00
	Apr	0.08	0.35	0.14	0.17	0.28	0.00
	May	0.08	0.35	0.14	0.17	0.28	0.00
	Jun	0.08	0.35	0.14	0.17	0.28	0.00
	Jul	0.08	0.35	0.14	0.17	0.28	0.00
	Aug	0.08	0.35	0.14	0.17	0.28	0.00
	Sep	0.08	0.35	0.14	0.17	0.28	0.00
	Oct	0.08	0.35	0.14	0.17	0.28	0.00
	Nov	0.08	0.35	0.14	0.17	0.28	0.00
	Dec	0.08	0.35	0.14	0.17	0.28	0.00
SiBluStm	Jan	0.04	0.18	0.15	0.31	0.32	0.00
	Feb	0.04	0.18	0.15	0.31	0.32	0.00
	Mar	0.04	0.18	0.15	0.31	0.32	0.00
	Apr	0.04	0.18	0.15	0.31	0.32	0.00
	May	0.04	0.18	0.15	0.31	0.32	0.00
	Jun	0.04	0.18	0.15	0.31	0.32	0.00
	Jul	0.04	0.18	0.15	0.31	0.32	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
SiBluStm (cont)	Aug	0.04	0.18	0.15	0.31	0.32	0.00
	Sep	0.04	0.18	0.15	0.31	0.32	0.00
	Oct	0.04	0.18	0.15	0.31	0.32	0.00
	Nov	0.04	0.18	0.15	0.31	0.32	0.00
	Dec	0.04	0.18	0.15	0.31	0.32	0.00
SdOtsGrm	Jan	0.07	0.18	0.10	0.25	0.40	0.00
	Feb	0.07	0.18	0.10	0.25	0.40	0.00
	Mar	0.07	0.18	0.10	0.25	0.40	0.00
	Apr	0.07	0.18	0.10	0.25	0.40	0.00
	May	0.07	0.18	0.10	0.25	0.40	0.00
	Jun	0.07	0.18	0.10	0.25	0.40	0.00
	Jul	0.07	0.18	0.10	0.25	0.40	0.00
	Aug	0.07	0.18	0.10	0.25	0.40	0.00
	Sep	0.07	0.18	0.10	0.25	0.40	0.00
	Oct	0.07	0.18	0.10	0.25	0.40	0.00
	Nov	0.07	0.18	0.10	0.25	0.40	0.00
	Dec	0.07	0.18	0.10	0.25	0.40	0.00
HryGrm	Jan	0.02	0.17	0.10	0.08	0.63	0.00
	Feb	0.02	0.17	0.10	0.08	0.63	0.00
	Mar	0.02	0.17	0.10	0.08	0.63	0.00
	Apr	0.02	0.17	0.10	0.08	0.63	0.00
	May	0.02	0.17	0.10	0.08	0.63	0.00
	Jun	0.02	0.17	0.10	0.08	0.63	0.00
	Jul	0.02	0.17	0.10	0.08	0.63	0.00
	Aug	0.02	0.17	0.10	0.08	0.63	0.00
	Sep	0.02	0.17	0.10	0.08	0.63	0.00
	Oct	0.02	0.17	0.10	0.08	0.63	0.00
	Nov	0.02	0.17	0.10	0.08	0.63	0.00
	Dec	0.02	0.17	0.10	0.08	0.63	0.00
BrmdaGrs	Jan	0.06	0.24	0.11	0.39	0.20	0.00
	Feb	0.06	0.24	0.11	0.39	0.20	0.00
	Mar	0.06	0.24	0.11	0.39	0.20	0.00
	Apr	0.06	0.24	0.11	0.39	0.20	0.00
	May	0.06	0.24	0.11	0.39	0.20	0.00
	Jun	0.06	0.24	0.11	0.39	0.20	0.00
	Jul	0.06	0.24	0.11	0.39	0.20	0.00
	Aug	0.06	0.24	0.11	0.39	0.20	0.00
	Sep	0.06	0.24	0.11	0.39	0.20	0.00
	Oct	0.06	0.24	0.11	0.39	0.20	0.00
	Nov	0.06	0.24	0.11	0.39	0.20	0.00
	Dec	0.06	0.24	0.11	0.39	0.20	0.00
TxCupGrs	Jan	0.05	0.37	0.13	0.20	0.25	0.00
	Feb	0.05	0.37	0.13	0.20	0.25	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
TxCupGrs (cont)	Mar	0.05	0.37	0.13	0.20	0.25	0.00
	Apr	0.05	0.37	0.13	0.20	0.25	0.00
	May	0.05	0.37	0.13	0.20	0.25	0.00
	Jun	0.05	0.37	0.13	0.20	0.25	0.00
	Jul	0.05	0.37	0.13	0.20	0.25	0.00
	Aug	0.05	0.37	0.13	0.20	0.25	0.00
	Sep	0.05	0.37	0.13	0.20	0.25	0.00
	Oct	0.05	0.37	0.13	0.20	0.25	0.00
	Nov	0.05	0.37	0.13	0.20	0.25	0.00
	Dec	0.05	0.37	0.13	0.20	0.25	0.00
SpMuhly	Jan	0.02	0.09	0.20	0.20	0.49	0.00
	Feb	0.02	0.09	0.20	0.20	0.49	0.00
	Mar	0.02	0.09	0.20	0.20	0.49	0.00
	Apr	0.02	0.09	0.20	0.20	0.49	0.00
	May	0.02	0.09	0.20	0.20	0.49	0.00
	Jun	0.02	0.09	0.20	0.20	0.49	0.00
	Jul	0.02	0.09	0.20	0.20	0.49	0.00
	Aug	0.02	0.09	0.20	0.20	0.49	0.00
	Sep	0.02	0.09	0.20	0.20	0.49	0.00
	Oct	0.02	0.09	0.20	0.20	0.49	0.00
	Nov	0.02	0.09	0.20	0.20	0.49	0.00
	Dec	0.02	0.09	0.20	0.20	0.49	0.00
LIBluStm	Jan	0.04	0.16	0.20	0.30	0.30	0.00
	Feb	0.04	0.16	0.20	0.30	0.30	0.00
	Mar	0.04	0.16	0.20	0.30	0.30	0.00
	Apr	0.04	0.16	0.20	0.30	0.30	0.00
	May	0.04	0.16	0.20	0.30	0.30	0.00
	Jun	0.04	0.16	0.20	0.30	0.30	0.00
	Jul	0.04	0.16	0.20	0.30	0.30	0.00
	Aug	0.04	0.16	0.20	0.30	0.30	0.00
	Sep	0.04	0.16	0.20	0.30	0.30	0.00
	Oct	0.04	0.16	0.20	0.30	0.30	0.00
	Nov	0.04	0.16	0.20	0.30	0.30	0.00
	Dec	0.04	0.16	0.20	0.30	0.30	0.00
IndnGrs	Jan	0.08	0.35	0.15	0.22	0.20	0.00
	Feb	0.08	0.35	0.15	0.22	0.20	0.00
	Mar	0.08	0.35	0.15	0.22	0.20	0.00
	Apr	0.08	0.35	0.15	0.22	0.20	0.00
	May	0.08	0.35	0.15	0.22	0.20	0.00
	Jun	0.08	0.35	0.15	0.22	0.20	0.00
	Jul	0.08	0.35	0.15	0.22	0.20	0.00
	Aug	0.08	0.35	0.15	0.22	0.20	0.00
	Sep	0.08	0.35	0.15	0.22	0.20	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
IndnGrs (cont)	Oct	0.08	0.35	0.15	0.22	0.20	0.00
	Nov	0.08	0.35	0.15	0.22	0.20	0.00
	Dec	0.08	0.35	0.15	0.22	0.20	0.00
TlDrpSd	Jan	0.08	0.30	0.14	0.22	0.26	0.00
	Feb	0.08	0.30	0.14	0.22	0.26	0.00
	Mar	0.08	0.30	0.14	0.22	0.26	0.00
	Apr	0.08	0.30	0.14	0.22	0.26	0.00
	May	0.08	0.30	0.14	0.22	0.26	0.00
	Jun	0.08	0.30	0.14	0.22	0.26	0.00
	Jul	0.08	0.30	0.14	0.22	0.26	0.00
	Aug	0.08	0.30	0.14	0.22	0.26	0.00
	Sep	0.08	0.30	0.14	0.22	0.26	0.00
	Oct	0.08	0.30	0.14	0.22	0.26	0.00
	Nov	0.08	0.30	0.14	0.22	0.26	0.00
	Dec	0.08	0.30	0.14	0.22	0.26	0.00
TxWntGrs	Jan	0.04	0.38	0.14	0.14	0.30	0.00
	Feb	0.04	0.38	0.14	0.14	0.30	0.00
	Mar	0.04	0.38	0.14	0.14	0.30	0.00
	Apr	0.04	0.38	0.14	0.14	0.30	0.00
	May	0.04	0.38	0.14	0.14	0.30	0.00
	Jun	0.04	0.38	0.14	0.14	0.30	0.00
	Jul	0.04	0.38	0.14	0.14	0.30	0.00
	Aug	0.04	0.38	0.14	0.14	0.30	0.00
	Sep	0.04	0.38	0.14	0.14	0.30	0.00
	Oct	0.04	0.38	0.14	0.14	0.30	0.00
	Nov	0.04	0.38	0.14	0.14	0.30	0.00
	Dec	0.04	0.38	0.14	0.14	0.30	0.00
CrlyMsqt	Jan	0.03	0.18	0.08	0.21	0.50	0.00
	Feb	0.03	0.18	0.08	0.21	0.50	0.00
	Mar	0.03	0.18	0.08	0.21	0.50	0.00
	Apr	0.03	0.18	0.08	0.21	0.50	0.00
	May	0.03	0.18	0.08	0.21	0.50	0.00
	Jun	0.03	0.18	0.08	0.21	0.50	0.00
	Jul	0.03	0.18	0.08	0.21	0.50	0.00
	Aug	0.03	0.18	0.08	0.21	0.50	0.00
	Sep	0.03	0.18	0.08	0.21	0.50	0.00
	Oct	0.03	0.18	0.08	0.21	0.50	0.00
	Nov	0.03	0.18	0.08	0.21	0.50	0.00
	Dec	0.03	0.18	0.08	0.21	0.50	0.00
BrmWd	Jan	0.15	0.16	0.23	0.20	0.26	0.00
	Feb	0.15	0.16	0.23	0.20	0.26	0.00
	Mar	0.15	0.16	0.23	0.20	0.26	0.00
	Apr	0.15	0.16	0.23	0.20	0.26	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
BrmWd (cont)	May	0.15	0.16	0.23	0.20	0.26	0.00
	Jun	0.15	0.16	0.23	0.20	0.26	0.00
	Jul	0.15	0.16	0.23	0.20	0.26	0.00
	Aug	0.15	0.16	0.23	0.20	0.26	0.00
	Sep	0.15	0.16	0.23	0.20	0.26	0.00
	Oct	0.15	0.16	0.23	0.20	0.26	0.00
	Nov	0.15	0.16	0.23	0.20	0.26	0.00
	Dec	0.15	0.16	0.23	0.20	0.26	0.00
WdSedge	Jan	0.03	0.20	0.33	0.04	0.40	0.00
	Feb	0.03	0.20	0.33	0.04	0.40	0.00
	Mar	0.03	0.20	0.33	0.04	0.40	0.00
	Apr	0.03	0.20	0.33	0.04	0.40	0.00
	May	0.03	0.20	0.33	0.04	0.40	0.00
	Jun	0.03	0.20	0.33	0.04	0.40	0.00
	Jul	0.03	0.20	0.33	0.04	0.40	0.00
	Aug	0.03	0.20	0.33	0.04	0.40	0.00
	Sep	0.03	0.20	0.33	0.04	0.40	0.00
	Oct	0.03	0.20	0.33	0.04	0.40	0.00
	Nov	0.03	0.20	0.33	0.04	0.40	0.00
	Dec	0.03	0.20	0.33	0.04	0.40	0.00
RbtTbaco	Jan	0.26	0.40	0.08	0.04	0.22	0.00
	Feb	0.26	0.40	0.08	0.04	0.22	0.00
	Mar	0.26	0.40	0.08	0.04	0.22	0.00
	Apr	0.26	0.40	0.08	0.04	0.22	0.00
	May	0.26	0.40	0.08	0.04	0.22	0.00
	Jun	0.26	0.40	0.08	0.04	0.22	0.00
	Jul	0.26	0.40	0.08	0.04	0.22	0.00
	Aug	0.26	0.40	0.08	0.04	0.22	0.00
	Sep	0.26	0.40	0.08	0.04	0.22	0.00
	Oct	0.26	0.40	0.08	0.04	0.22	0.00
	Nov	0.26	0.40	0.08	0.04	0.22	0.00
	Dec	0.26	0.40	0.08	0.04	0.22	0.00
PrrBluet	Jan	0.14	0.15	0.15	0.20	0.36	0.00
	Feb	0.14	0.15	0.15	0.20	0.36	0.00
	Mar	0.14	0.15	0.15	0.20	0.36	0.00
	Apr	0.14	0.15	0.15	0.20	0.36	0.00
	May	0.14	0.15	0.15	0.20	0.36	0.00
	Jun	0.14	0.15	0.15	0.20	0.36	0.00
	Jul	0.14	0.15	0.15	0.20	0.36	0.00
	Aug	0.14	0.15	0.15	0.20	0.36	0.00
	Sep	0.14	0.15	0.15	0.20	0.36	0.00
	Oct	0.14	0.15	0.15	0.20	0.36	0.00
	Nov	0.14	0.15	0.15	0.20	0.36	0.00
	Dec	0.14	0.15	0.15	0.20	0.36	0.00

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Species	Month	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
PrCnflwr	Jan	0.15	0.15	0.24	0.10	0.36	0.00
	Feb	0.15	0.15	0.24	0.10	0.36	0.00
	Mar	0.15	0.15	0.24	0.10	0.36	0.00
	Apr	0.15	0.15	0.24	0.10	0.36	0.00
	May	0.15	0.15	0.24	0.10	0.36	0.00
	Jun	0.15	0.15	0.24	0.10	0.36	0.00
	Jul	0.15	0.15	0.24	0.10	0.36	0.00
	Aug	0.15	0.15	0.24	0.10	0.36	0.00
	Sep	0.15	0.15	0.24	0.10	0.36	0.00
	Oct	0.15	0.15	0.24	0.10	0.36	0.00
	Nov	0.15	0.15	0.24	0.10	0.36	0.00
	Dec	0.15	0.15	0.24	0.10	0.36	0.00
TxSage	Jan	0.24	0.36	0.10	0.05	0.25	0.00
	Feb	0.24	0.36	0.10	0.05	0.25	0.00
	Mar	0.24	0.36	0.10	0.05	0.25	0.00
	Apr	0.24	0.36	0.10	0.05	0.25	0.00
	May	0.24	0.36	0.10	0.05	0.25	0.00
	Jun	0.24	0.36	0.10	0.05	0.25	0.00
	Jul	0.24	0.36	0.10	0.05	0.25	0.00
	Aug	0.24	0.36	0.10	0.05	0.25	0.00
	Sep	0.24	0.36	0.10	0.05	0.25	0.00
	Oct	0.24	0.36	0.10	0.05	0.25	0.00
	Nov	0.24	0.36	0.10	0.05	0.25	0.00
	Dec	0.24	0.36	0.10	0.05	0.25	0.00
DoveWeed	Jan	0.05	0.15	0.20	0.10	0.50	0.00
	Feb	0.05	0.15	0.20	0.10	0.50	0.00
	Mar	0.05	0.15	0.20	0.10	0.50	0.00
	Apr	0.05	0.15	0.20	0.10	0.50	0.00
	May	0.05	0.15	0.20	0.10	0.50	0.00
	Jun	0.05	0.15	0.20	0.10	0.50	0.00
	Jul	0.05	0.15	0.20	0.10	0.50	0.00
	Aug	0.05	0.15	0.20	0.10	0.50	0.00
	Sep	0.05	0.15	0.20	0.10	0.50	0.00
	Oct	0.05	0.15	0.20	0.10	0.50	0.00
	Nov	0.05	0.15	0.20	0.10	0.50	0.00
	Dec	0.05	0.15	0.20	0.10	0.50	0.00

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Note: Allocation is the proportion of new growth biomass that is allocated to different plant components.

Table B3. SeedMonthAllocation matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NIHckbry	0.13	0.37	0.10	0.07	0.14	0.19
TxPrsmmn	0.14	0.38	0.09	0.07	0.14	0.18
AsheJunp	0.11	0.32	0.10	0.10	0.27	0.10
ShRdOak	0.14	0.38	0.10	0.07	0.13	0.18
LvOak	0.14	0.39	0.15	0.16	0.10	0.06
CdrElm	0.13	0.38	0.10	0.07	0.13	0.19
Mesquite	0.10	0.30	0.02	0.07	0.19	0.32
Sotol	0.10	0.30	0.00	0.00	0.35	0.25
EvgSumac	0.10	0.28	0.09	0.12	0.18	0.23
GrnBriar	0.00	0.15	0.00	0.30	0.27	0.28
MtnGrape	0.10	0.28	0.11	0.05	0.27	0.19
AnnlGrs	0.00	0.37	0.00	0.20	0.12	0.40
OfThrAn	0.00	0.00	0.00	0.20	0.00	0.80
KRBluStm	0.00	0.35	0.00	0.19	0.19	0.27
SiBluStm	0.00	0.18	0.00	0.16	0.29	0.37
SdOtsGrm	0.00	0.48	0.00	0.05	0.20	0.27
HryGrm	0.00	0.17	0.00	0.08	0.57	0.18
BrmdaGrs	0.00	0.24	0.00	0.39	0.10	0.27
TxCupGrs	0.00	0.37	0.00	0.20	0.12	0.40
SpMuhly	0.00	0.09	0.00	0.20	0.24	0.47
LlBluStm	0.00	0.16	0.00	0.27	0.27	0.30
IndnGrs	0.00	0.35	0.00	0.22	0.10	0.33
TlDrpSd	0.00	0.30	0.00	0.19	0.23	0.28
TxWntGrs	0.00	0.38	0.00	0.07	0.27	0.28
CrlyMsqt	0.00	0.18	0.00	0.28	0.28	0.26
BrmWd	0.00	0.00	0.00	0.10	0.03	0.83
WdSedge	0.00	0.20	0.00	0.04	0.20	0.56
RbtTbaco	0.00	0.40	0.00	0.04	0.11	0.45
PrrBluet	0.00	0.15	0.00	0.10	0.32	0.43
PrCnflwr	0.00	0.15	0.00	0.05	0.18	0.62
TxSage	0.00	0.36	0.00	0.05	0.12	0.47
DoveWeed	0.00	0.00	0.00	0.00	0.15	0.85

Note: SeedMonthAllocation is the new growth allocation during seed producing months.

Table B4. GreenOutAllocation matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NlHckbry	0.00	0.35	0.15	0.15	0.35	0.00
TxPrsmmn	0.00	0.35	0.15	0.15	0.35	0.00
AsheJunp	0.00	0.30	0.15	0.20	0.35	0.00
ShRdOak	0.00	0.35	0.20	0.15	0.30	0.00
LvOak	0.00	0.35	0.15	0.15	0.35	0.00
CdrElm	0.00	0.35	0.15	0.15	0.35	0.00
Mesquite	0.00	0.40	0.10	0.13	0.37	0.00
Sotol	0.00	0.30	0.00	0.05	0.65	0.00
EvgSumac	0.00	0.25	0.15	0.30	0.30	0.00
GrnBriar	0.00	0.10	0.00	0.20	0.70	0.00
MtnGrape	0.00	0.25	0.20	0.15	0.40	0.00
AnnlGrs	0.00	0.35	0.00	0.25	0.40	0.00
OfThrAn	0.00	0.30	0.00	0.10	0.60	0.00
KRBluStm	0.00	0.30	0.00	0.20	0.50	0.00
SiBluStm	0.00	0.15	0.00	0.40	0.45	0.00
SdOtsGrm	0.00	0.45	0.00	0.10	0.45	0.00
HryGrm	0.00	0.15	0.00	0.00	0.85	0.00
BrmdaGrs	0.00	0.20	0.00	0.49	0.31	0.00
TxCupGrs	0.00	0.35	0.00	0.25	0.40	0.00
SpMuhly	0.00	0.10	0.00	0.20	0.70	0.00
LlBluStm	0.00	0.15	0.00	0.40	0.45	0.00
IndnGrs	0.00	0.35	0.00	0.25	0.40	0.00
TlDrpSd	0.00	0.25	0.00	0.30	0.45	0.00
TxWntGrs	0.00	0.30	0.00	0.15	0.55	0.00
CrlyMsqt	0.00	0.15	0.00	0.10	0.75	0.00
BrmWd	0.00	0.10	0.25	0.20	0.45	0.00
WdSedge	0.00	0.20	0.00	0.04	0.76	0.00
RbtTbaco	0.00	0.40	0.00	0.05	0.55	0.00
PrrBluet	0.00	0.10	0.00	0.10	0.80	0.00
PrCnflwr	0.00	0.10	0.15	0.05	0.70	0.00
TxSage	0.00	0.35	0.00	0.10	0.55	0.00
DoveWeed	0.00	0.05	0.00	0.35	0.60	0.00

Note: GreenOutAllocation is the new growth allocation during spring green-out months.

Table B5. PlantNConc matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0.0060	0.0125	0.0030	0.0063	0.0140	0.0060	0.0058	0.0090	0.0130	0.0150	0.0060
TxPrsmmn	0.0062	0.0126	0.0031	0.0064	0.0142	0.0061	0.0060	0.0092	0.0132	0.0152	0.0062
AsheJunp	0.0040	0.0110	0.0030	0.0040	0.0118	0.0092	0.0030	0.0095	0.0120	0.0120	0.0092
ShRdOak	0.0051	0.0097	0.0030	0.0063	0.0142	0.0045	0.0058	0.0071	0.0100	0.0150	0.0045
LvOak	0.0051	0.0095	0.0030	0.0063	0.0155	0.0053	0.0058	0.0078	0.0100	0.0160	0.0053
CdrElm	0.0059	0.0123	0.0029	0.0062	0.0138	0.0059	0.0057	0.0088	0.0128	0.0148	0.0059
Mesquite	0.0160	0.0168	0.0129	0.0140	0.0303	0.0308	0.0135	0.0250	0.0170	0.0310	0.0300
Sotol	0.0120	0.0130	0.0150	0.0095	0.0180	0.0190	0.0090	0.0095	0.0125	0.0190	0.0190
EvgSumac	0.0114	0.0118	0.0116	0.0124	0.0180	0.0185	0.0105	0.0140	0.0137	0.0195	0.0186
GrnBriar	0.0222	0.0226	0.0224	0.0226	0.0229	0.0200	0.0180	0.0180	0.0230	0.0235	0.0200
MtnGrape	0.0115	0.0125	0.0085	0.0090	0.0180	0.0185	0.0070	0.0135	0.0097	0.0190	0.0185
AnnlGrs	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0090	0.0095	0.0120	0.0125	0.0200
OfThrAn	0.0084	0.0085	0.0093	0.0094	0.0096	0.0173	0.0071	0.0071	0.0085	0.0113	0.0173
KRBluStm	0.0070	0.0072	0.0071	0.0072	0.0074	0.0200	0.0063	0.0063	0.0072	0.0074	0.0200
SiBluStm	0.0098	0.0100	0.0099	0.0100	0.0123	0.0200	0.0080	0.0080	0.0100	0.0125	0.0200
SdOtsGrm	0.0100	0.0102	0.0100	0.0102	0.0125	0.0200	0.0085	0.0085	0.0102	0.0130	0.0200
HryGrm	0.0080	0.0082	0.0081	0.0082	0.0084	0.0200	0.0072	0.0072	0.0082	0.0087	0.0200
BrmdaGrs	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0094	0.0110	0.0107	0.0115	0.0200
TxCupGrs	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0090	0.0095	0.0120	0.0125	0.0200
SpMuhly	0.0104	0.0111	0.0121	0.0132	0.0137	0.0200	0.0121	0.0127	0.0137	0.0140	0.0200
LlBluStm	0.0100	0.0102	0.0100	0.0100	0.0125	0.0200	0.0080	0.0071	0.0105	0.0130	0.0200
IndnGrs	0.0102	0.0104	0.0102	0.0102	0.0126	0.0220	0.0082	0.0072	0.0107	0.0132	0.0220
TlDrpSd	0.0070	0.0080	0.0100	0.0104	0.0106	0.0200	0.0090	0.0095	0.0085	0.0110	0.0200
TxWntGrs	0.0120	0.0130	0.0130	0.0130	0.0135	0.0200	0.0120	0.0120	0.0130	0.0140	0.0200
CrlyMsqt	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0094	0.0110	0.0107	0.0115	0.0200
BrmWd	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0054	0.0057	0.0110	0.0120	0.0200
WdSedge	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0105	0.0110	0.0115	0.0125	0.0200
RbtTbaco	0.0190	0.0190	0.0190	0.0190	0.0198	0.0280	0.0102	0.0110	0.0296	0.0296	0.0280
PrrBluet	0.0109	0.0113	0.0111	0.0113	0.0119	0.0200	0.0100	0.0105	0.0115	0.0125	0.0200
PrCnflwr	0.0144	0.0146	0.0145	0.0146	0.0147	0.0200	0.0130	0.0135	0.0150	0.0160	0.0200
TxSage	0.0146	0.0148	0.0146	0.0148	0.0150	0.0210	0.0128	0.0132	0.0186	0.0188	0.0210
DoveWeed	0.0090	0.0100	0.0110	0.0130	0.0190	0.0250	0.0120	0.0150	0.0110	0.0200	0.0270

Note: PlantNConc is the typical total N concentration for each component of each plant species.
SD: Standing Dead
Sdlg: Seedling

Table B6. Required PlantNConc matrix.

Species	Min	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0.75	0.0060	0.0125	0.0030	0.0063	0.0140	0.0060	0.0058	0.0090	0.0130	0.0150	0.0060
TxPrsmmn	0.75	0.0062	0.0126	0.0031	0.0064	0.0142	0.0061	0.0060	0.0092	0.0132	0.0152	0.0062
AsheJunp	0.75	0.0040	0.0110	0.0030	0.0040	0.0118	0.0092	0.0030	0.0095	0.0120	0.0120	0.0092
ShRdOak	0.75	0.0051	0.0097	0.0030	0.0063	0.0142	0.0045	0.0058	0.0071	0.0100	0.0150	0.0045
LvOak	0.75	0.0051	0.0095	0.0030	0.0063	0.0155	0.0053	0.0058	0.0078	0.0100	0.0160	0.0053
CdrElm	0.75	0.0059	0.0123	0.0029	0.0062	0.0138	0.0059	0.0057	0.0088	0.0128	0.0148	0.0059
Mesquite	0.75	0.0160	0.0168	0.0129	0.0140	0.0303	0.0308	0.0135	0.0250	0.0170	0.0310	0.0300
Sotol	0.75	0.0120	0.0130	0.0150	0.0095	0.0180	0.0190	0.0090	0.0095	0.0125	0.0190	0.0190
EvgSumac	0.75	0.0114	0.0118	0.0116	0.0124	0.0180	0.0185	0.0105	0.0140	0.0137	0.0195	0.0186
GrnBriar	0.75	0.0222	0.0226	0.0224	0.0226	0.0229	0.0200	0.0180	0.0180	0.0230	0.0235	0.0200
MtnGrape	0.75	0.0115	0.0125	0.0085	0.0090	0.0180	0.0185	0.0070	0.0135	0.0097	0.0190	0.0185
AnnlGrs	0.75	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0090	0.0095	0.0120	0.0125	0.0200
OfThrAn	0.75	0.0084	0.0085	0.0093	0.0094	0.0096	0.0173	0.0071	0.0071	0.0085	0.0113	0.0173
KRBluStm	0.75	0.0070	0.0072	0.0071	0.0072	0.0074	0.0200	0.0063	0.0063	0.0072	0.0074	0.0200
SiBluStm	0.75	0.0098	0.0100	0.0099	0.0100	0.0123	0.0200	0.0080	0.0080	0.0100	0.0125	0.0200
SdOtsGrm	0.75	0.0100	0.0102	0.0100	0.0102	0.0125	0.0200	0.0085	0.0085	0.0102	0.0130	0.0200
HryGrm	0.75	0.0080	0.0082	0.0081	0.0082	0.0084	0.0200	0.0072	0.0072	0.0082	0.0087	0.0200
BrmdaGrs	0.75	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0094	0.0110	0.0107	0.0115	0.0200
TxCupGrs	0.75	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0090	0.0095	0.0120	0.0125	0.0200
SpMuhly	0.75	0.0104	0.0111	0.0121	0.0132	0.0137	0.0200	0.0121	0.0127	0.0137	0.0140	0.0200
LlBluStm	0.75	0.0100	0.0102	0.0100	0.0100	0.0125	0.0200	0.0080	0.0071	0.0105	0.0130	0.0200
IndnGrs	0.75	0.0102	0.0104	0.0102	0.0102	0.0126	0.0220	0.0082	0.0072	0.0107	0.0132	0.0220
TlDrpSd	0.75	0.0070	0.0080	0.0100	0.0104	0.0106	0.0200	0.0090	0.0095	0.0085	0.0110	0.0200
TxWntGrs	0.75	0.0120	0.0130	0.0130	0.0130	0.0135	0.0200	0.0120	0.0120	0.0130	0.0140	0.0200
CrlyMsqt	0.75	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0094	0.0110	0.0107	0.0115	0.0200
BrmWd	0.75	0.0104	0.0107	0.0106	0.0107	0.0113	0.0200	0.0054	0.0057	0.0110	0.0120	0.0200
WdSedge	0.75	0.0095	0.0100	0.0110	0.0110	0.0120	0.0200	0.0105	0.0110	0.0115	0.0125	0.0200
RbtTbaco	0.75	0.0190	0.0190	0.0190	0.0190	0.0198	0.0280	0.0102	0.0110	0.0296	0.0296	0.0280
PrrBluet	0.75	0.0109	0.0113	0.0111	0.0113	0.0119	0.0200	0.0100	0.0105	0.0115	0.0125	0.0200
PrCnflwr	0.75	0.0144	0.0146	0.0145	0.0146	0.0147	0.0200	0.0130	0.0135	0.0150	0.0160	0.0200
TxSage	0.75	0.0146	0.0148	0.0146	0.0148	0.0150	0.0210	0.0128	0.0132	0.0186	0.0188	0.0210
DoveWeed	0.75	0.0090	0.0100	0.0110	0.0130	0.0190	0.0250	0.0120	0.0150	0.0110	0.0200	0.0270

Note: Min is the minimum concentration needed for maintenance of plant biomass. Component values are minimum N concentrations needed for new growth.

Table B7. Nitrogen resorption matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NIHckbry	0.15	0.10	0.00	0.15	0.20	0.00
TxPrsmmn	0.15	0.10	0.00	0.15	0.20	0.00
AsheJunp	0.15	0.10	0.00	0.15	0.20	0.00
ShRdOak	0.15	0.10	0.00	0.15	0.20	0.00
LvOak	0.15	0.10	0.00	0.15	0.20	0.00
CdrElm	0.15	0.10	0.00	0.15	0.20	0.00
Mesquite	0.10	0.05	0.00	0.05	0.10	0.00
Sotol	0.10	0.05	0.00	0.05	0.10	0.00
EvgSumac	0.10	0.05	0.00	0.05	0.20	0.00
GrnBriar	0.10	0.05	0.00	0.10	0.20	0.00
MtnGrape	0.10	0.05	0.00	0.05	0.20	0.00
AnnlGrs	0.05	0.03	0.00	0.05	0.05	0.00
OfThrAn	0.00	0.00	0.00	0.00	0.00	0.00
KRBluStm	0.10	0.05	0.05	0.05	0.10	0.00
SiBluStm	0.10	0.05	0.00	0.05	0.10	0.00
SdOtsGrm	0.10	0.05	0.00	0.05	0.10	0.00
HryGrm	0.05	0.03	0.00	0.05	0.05	0.00
BrmdaGrs	0.05	0.03	0.05	0.05	0.05	0.00
TxCupGrs	0.05	0.03	0.00	0.05	0.05	0.00
SpMuhly	0.05	0.03	0.00	0.05	0.05	0.00
LIBluStm	0.10	0.05	0.00	0.05	0.10	0.00
IndnGrs	0.10	0.05	0.00	0.05	0.10	0.00
TIDrpSd	0.10	0.05	0.00	0.05	0.10	0.00
TxWntGrs	0.05	0.03	0.00	0.05	0.10	0.00
CrlyMsqt	0.05	0.03	0.05	0.05	0.05	0.00
BrmWd	0.00	0.00	0.00	0.00	0.00	0.00
WdSedge	0.05	0.03	0.00	0.00	0.10	0.00
RbtTbaco	0.00	0.00	0.00	0.00	0.00	0.00
PrrBluet	0.05	0.03	0.00	0.05	0.10	0.00
PrCnflwr	0.05	0.03	0.00	0.05	0.10	0.00
TxSage	0.05	0.03	0.00	0.05	0.05	0.00
DoveWeed	0.10	0.05	0.00	0.05	0.05	0.00

Note: N resorption is the percentage of N withdrawn from a plant component before it incurs dieback.

Table B8. Root architecture matrix.

	Percent of Soil Profile Depth											Max. Root Depth (cm)
Species	0-1	1-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
NlHckbry	0.02	0.06	0.08	0.15	0.10	0.15	0.13	0.1	0.1	0.06	0.03	0.02	10150
TxPrsmmn	0.03	0.07	0.09	0.16	0.12	0.15	0.14	0.08	0.06	0.05	0.03	0.02	7300
AsheJunp	0.02	0.06	0.08	0.15	0.11	0.15	0.14	0.09	0.09	0.06	0.03	0.02	12190
ShRdOak	0.02	0.06	0.09	0.15	0.15	0.10	0.12	0.1	0.09	0.06	0.04	0.02	11500
LvOak	0.02	0.06	0.08	0.15	0.11	0.15	0.14	0.09	0.09	0.06	0.02	0.02	7300
CdrElm	0.02	0.06	0.09	0.15	0.12	0.15	0.12	0.1	0.08	0.06	0.03	0.02	7300
Mesquite	0.04	0.06	0.15	0.20	0.15	0.12	0.10	0.06	0.05	0.03	0.02	0.02	24380
Sotol	0.06	0.10	0.25	0.25	0.15	0.10	0.02	0.02	0.02	0.01	0.01	0.01	1080
EvgSumac	0.04	0.06	0.20	0.16	0.12	0.10	0.08	0.07	0.07	0.06	0.03	0.01	1980
GrnBriar	0.06	0.16	0.20	0.20	0.15	0.10	0.06	0.03	0.01	0.01	0.01	0.01	1500
MtnGrape	0.10	0.12	0.25	0.20	0.20	0.05	0.03	0.01	0.01	0.01	0.01	0.01	1500
AnnlGrs	0.20	0.20	0.24	0.14	0.10	0.04	0.03	0.01	0.01	0.01	0.01	0.01	940
OfThrAn	0.20	0.20	0.20	0.14	0.10	0.06	0.04	0.02	0.01	0.01	0.01	0.01	1400
KRBluStm	0.08	0.22	0.28	0.15	0.09	0.05	0.03	0.03	0.02	0.02	0.02	0.01	2400
SiBluStm	0.12	0.34	0.27	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.01	2500
SdOtsGrm	0.13	0.37	0.30	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	3960
HryGrm	0.24	0.19	0.22	0.20	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	1070
BrmdaGrs	0.22	0.20	0.22	0.20	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01	1500
TxCupGrs	0.20	0.20	0.24	0.14	0.10	0.04	0.03	0.01	0.01	0.01	0.01	0.01	940
SpMuhly	0.20	0.20	0.18	0.15	0.10	0.06	0.05	0.02	0.01	0.01	0.01	0.01	1200
LlBluStm	0.12	0.35	0.28	0.08	0.06	0.04	0.02	0.01	0.01	0.01	0.01	0.01	2440
IndnGrs	0.20	0.25	0.20	0.12	0.08	0.05	0.04	0.02	0.01	0.01	0.01	0.01	2430
TlDrpSd	0.09	0.21	0.23	0.12	0.10	0.08	0.06	0.04	0.03	0.02	0.02	0.01	2130
TxWntGrs	0.08	0.08	0.11	0.14	0.12	0.12	0.12	0.07	0.06	0.05	0.03	0.02	1950
CrlyMsqt	0.22	0.20	0.22	0.20	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01	1830
BrmWd	0.06	0.20	0.20	0.24	0.10	0.06	0.05	0.04	0.02	0.01	0.01	0.01	900
WdSedge	0.20	0.20	0.20	0.14	0.10	0.06	0.04	0.02	0.01	0.01	0.01	0.01	1600
RbtTbaco	0.06	0.15	0.18	0.26	0.10	0.08	0.05	0.04	0.03	0.02	0.02	0.01	1200
PrrBluet	0.08	0.30	0.34	0.12	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	610
PrCnflwr	0.09	0.30	0.40	0.10	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	1830
TxSage	0.08	0.16	0.16	0.24	0.12	0.08	0.06	0.04	0.02	0.02	0.01	0.01	1560
DoveWeed	0.08	0.30	0.34	0.12	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	610

Note: Root architecture is the percentage of total root biomass by percentage of soil depth. Also included is the maximum rooting depth by species.

Table B9. Root efficiency matrices.

Species	Uptake Capacity	Saturation Death Loss	Biomass Adjustment
NIHckbry	0.1	0.60	0.90
TxPrsmmn	0.1	0.65	1.00
AsheJunp	0.1	0.60	1.00
ShRdOak	0.1	0.60	1.00
LvOak	0.1	0.60	1.00
CdrElm	0.1	0.60	0.90
Mesquite	0.1	0.60	1.00
Sotol	0.1	0.80	1.00
EvgSumac	0.1	0.75	1.00
GrnBriar	0.1	0.85	1.00
MtnGrape	0.1	0.75	1.00
AnnlGrs	0.1	1.00	0.70
OfThrAn	0.1	1.00	1.00
KRBluStm	0.1	0.95	1.00
SiBluStm	0.1	0.95	1.00
SdOtsGrm	0.1	0.95	1.00
HryGrm	0.1	1.00	1.00
BrmdaGrs	0.1	1.00	0.90
TxCupGrs	0.1	1.00	0.70
SpMuhly	0.1	1.00	0.50
LlBluStm	0.1	0.95	0.90
IndnGrs	0.1	0.95	0.80
TlDrpSd	0.1	0.95	1.00
TxWntGrs	0.1	1.00	1.00
CrlyMsqt	0.1	1.00	1.00
BrmWd	0.1	0.90	1.00
WdSedge	0.1	1.00	1.00
RbtTbaco	0.1	0.95	1.00
PrrBluet	0.1	0.10	0.90
PrCnflwr	0.1	0.95	1.00
TxSage	0.1	0.95	1.00
DoveWeed	0.2	0.75	1.00

Note: Uptake Capacity is the proportion of total monthly water demand that can be taken up in one day. Biomass Adjustment is relative per biomass uptake efficiency of roots of each species. Maximum is 1.

Table B10. Physiological month triggers.

Species	Green-out	Seed Sprout Start	Seed Sprout End	Seed Set Start	Seed Set End	Dormancy
NIHckbry	3	3	9	4	8	10
TxPrsmmn	2	2	9	3	8	10
AsheJunp	1	3	9	3	7	1
ShRdOak	3	3	8	4	8	10
LvOak	2	3	9	4	8	2
CdrElm	3	3	8	4	8	10
Mesquite	4	3	9	4	8	10
Sotol	1	2	10	6	7	1
EvgSumac	1	3	9	4	8	1
GrnBriar	9	9	6	2	6	7
MtnGrape	2	3	9	6	10	11
AnnlGrs	2	3	8	3	11	11
OfThrAn	3	3	10	8	11	11
KRBluStm	3	3	9	7	10	12
SiBluStm	4	3	8	5	9	11
SdOtsGrm	3	3	8	6	10	11
HryGrm	3	3	8	6	10	11
BrmdaGrs	3	3	8	5	10	11
TxCupGrs	2	3	8	3	11	11
SpMuhly	3	4	9	8	11	11
LIBluStm	4	3	8	8	10	11
IndnGrs	3	3	8	8	11	11
TlDrpSd	4	3	8	9	11	11
TxWntGrs	9	9	3	3	5	7
CrlyMsqt	3	3	8	5	10	11
BrmWd	3	3	8	6	9	10
WdSedge	3	4	9	5	9	11
RbtTbaco	2	2	6	3	5	7
PrrBluet	3	3	8	4	9	11
PrCnflwr	3	3	8	5	9	11
TxSage	2	2	6	3	5	7
DoveWeed	2	3	9	4	8	11

Note: Green-out is the month in which the species greens out from winter dormancy.

Seed sprout is the interval of months in which seeds in the Seed Bank can sprout, given appropriate water conditions.

Seed set is the interval of months in which mature plants produce seed, and the SeedMonthAllocation matrix is used.

Dormancy is the month in which the species enters winter dormancy.

Table B11. Biomass conversion constants.

Species	Dry wt/Wet wt	Moisture Interception g biomass	Basal Cover/ Trunk Biomass
NIHckbry	0.55	0.0089	1310
TxPrsmmn	0.55	0.0080	730
AsheJunp	0.55	0.0090	254
ShRdOak	0.55	0.0090	1848
LvOak	0.55	0.0092	696
CdrElm	0.55	0.0087	1310
Mesquite	0.50	0.0090	500
Sotol	0.40	0.0085	20
EvgSumac	0.35	0.0090	20
GrnBriar	0.39	0.0080	3
MtnGrape	0.30	0.0080	10
AnnlGrs	0.34	0.0084	2
OfThrAn	0.35	0.0084	1
KRBluStm	0.33	0.0085	3
SiBluStm	0.34	0.0086	3
SdOtsGrm	0.34	0.0086	4
HryGrm	0.35	0.0083	2
BrmdaGrs	0.36	0.0084	2
TxCupGrs	0.34	0.0084	2
SpMuhly	0.34	0.0082	1
LIBluStm	0.35	0.0086	3
IndnGrs	0.36	0.0088	4
TIDrpSd	0.35	0.0086	3
TxWntGrs	0.34	0.0084	2
CrlyMsqt	0.36	0.0084	2
BrmWd	0.40	0.0080	1
WdSedge	0.33	0.0085	1
RbtTbaco	0.30	0.0088	1
PrrBluet	0.30	0.0082	3
PrCnflwr	0.33	0.0083	3
TxSage	0.30	0.0084	2
DoveWeed	0.18	0.0050	40

Note: Dry wt / Wet wt is the typical ratio of dry biomass to wet biomass.

Moisture Interception is the precipitation depth (mm) intercepted by the species per g aboveground biomass.

Basal cover / Trunk biomass is the area of trunk (cm^2/m^2) covered by the species per g of trunk biomass.

Table B12. Water use factors.

Species	Maintenance (mm/g bio/mo)	New Biomass Maintenance	Water to Production	Green-out Water Use
NIHckbry	0.0000090	0.05	0.92	0.45
TxPrsmmn	0.0000080	0.04	0.64	0.45
AsheJunp	0.0000065	0.03	0.53	0.45
ShRdOak	0.0000085	0.04	0.90	0.45
LvOak	0.0000080	0.04	0.80	0.45
CdrElm	0.0000090	0.05	0.92	0.45
Mesquite	0.0000095	0.05	1.30	0.50
Sotol	0.0000075	0.04	0.51	0.60
EvgSumac	0.0000090	0.05	0.54	0.65
GrnBriar	0.0000180	0.05	1.08	0.61
MtnGrape	0.0000090	0.05	1.08	0.70
AnnlGrs	0.0000180	0.05	0.55	0.66
OfThrAn	0.0000150	0.04	0.56	0.65
KRBluStm	0.0000150	0.04	0.68	0.67
SiBluStm	0.0000170	0.06	0.71	0.66
SdOtsGrm	0.0000160	0.04	0.75	0.66
HryGrm	0.0000160	0.04	0.41	0.65
BrmdaGrs	0.0000136	0.03	0.31	0.64
TxCupGrs	0.0000180	0.05	0.55	0.66
SpMuhly	0.0000160	0.05	0.92	0.66
LIBluStm	0.0000170	0.06	0.70	0.65
IndnGrs	0.0000175	0.06	0.83	0.64
TIDrpSd	0.0000170	0.06	0.71	0.65
TxWntGrs	0.0000200	0.06	0.99	0.66
CrlyMsqt	0.0000150	0.04	0.43	0.64
BrmWd	0.0000180	0.05	0.42	0.60
WdSedge	0.0000200	0.06	0.79	0.67
RbtTbaco	0.0000200	0.05	0.86	0.70
PrrBluet	0.0000200	0.07	0.59	0.70
PrCnflwr	0.0000190	0.06	0.70	0.67
TxSage	0.0000220	0.04	0.65	0.70
DoveWeed	0.0000250	0.08	0.65	0.82

Note: Maintenance is the volume of water (mm) required for monthly physiological maintenance per g biomass.

New biomass maintenance is volume of water (mm) required for monthly physiological maintenance per g biomass for new (green-out) biomass.

Water to production is the volume of water (mm) required to produce 1 g of new biomass.

Green-out water use is a factor for adjusting water to production during green-out months.

Table B13. Growth rates.

Species	Maximum Growth Rate	Maximum Biomass	Maximum Old Biomass Drought Loss
NIHckbry	0.30	8000	0.35
TxPrsmmn	0.20	5000	0.20
AsheJunp	0.20	12000	0.25
ShRdOak	0.20	12000	0.30
LvOak	0.15	15000	0.25
CdrElm	0.30	9000	0.35
Mesquite	0.30	10000	0.30
Sotol	0.20	1200	0.15
EvgSumac	0.75	2000	0.30
GrnBriar	0.40	800	0.40
MtnGrape	0.40	2500	0.35
AnnlGrs	1.70	600	0.40
OfThrAn	1.75	400	0.40
KRBluStm	1.50	540	0.30
SiBluStm	1.40	600	0.40
SdOtsGrm	1.50	600	0.40
HryGrm	1.50	200	0.40
BrmdaGrs	1.71	450	0.30
TxCupGrs	1.70	600	0.40
SpMuhly	1.50	400	0.40
LIBluStm	1.50	650	0.40
IndnGrs	1.50	750	0.40
TIDrpSd	1.40	600	0.40
TxWntGrs	1.75	450	0.30
CrlyMsqt	1.25	250	0.30
BrmWd	2.20	300	0.50
WdSedge	1.40	250	0.50
RbtTbaco	1.80	150	0.50
PrrBluet	1.80	200	0.60
PrCnflwr	1.80	500	0.40
TxSage	1.80	400	0.40
DoveWeed	1.50	300	0.80

Note: Maximum growth rate is the maximum monthly percent increase in biomass.

Maximum old biomass drought loss is the maximum monthly percent decrease in old biomass due to drought stress.

Table B14. Monthly maximum growth rates.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NlHckbry	0.00	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
TxPrsmmn	0.00	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
AsheJunp	0.50	0.50	0.70	0.90	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.70
ShRdOak	0.00	0.00	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.40	0.10	0.00
LvOak	0.30	0.40	0.70	0.90	1.00	1.00	1.00	1.00	1.00	0.90	0.70	0.50
CdrElm	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.10	0.00
Mesquite	0.00	0.00	0.00	0.50	0.90	1.00	1.00	1.00	0.90	0.50	0.00	0.00
Sotol	0.40	0.40	0.70	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.40
EvgSumac	0.20	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.20
GrnBriar	0.50	0.50	0.80	1.00	1.00	0.80	0.40	0.00	0.40	1.00	1.00	0.50
MtnGrape	0.00	0.10	0.60	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.20	0.00
AnnlGrs	0.00	0.10	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.00
OfThrAn	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.70	0.30	0.10	0.00
KRBluStm	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	1.00	0.70	0.40	0.00
SiBluStm	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
SdOtsGrm	0.00	0.00	0.50	0.80	0.95	1.00	1.00	1.00	0.95	0.60	0.30	0.00
HryGrm	0.00	0.00	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.50	0.30	0.00
BrmdaGrs	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	1.00	0.70	0.40	0.00
TxCupGrs	0.00	0.10	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.00
SpMuhly	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.10	0.00
LlBluStm	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
IndnGrs	0.00	0.00	0.40	0.80	0.90	1.00	1.00	1.00	0.80	0.40	0.20	0.00
TlDrpSd	0.00	0.00	0.00	0.50	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00
TxWntGrs	0.80	0.90	1.00	1.00	0.80	0.50	0.20	0.00	0.40	1.00	1.00	0.90
CrlyMsqt	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	1.00	0.70	0.40	0.00
BrmWd	0.00	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.30	0.00	0.00
WdSedge	0.00	0.10	0.50	0.80	1.00	1.00	1.00	1.00	0.80	0.70	0.30	0.00
RbtTbaco	0.00	0.30	0.70	1.00	1.00	0.90	0.60	0.30	0.10	0.10	0.00	0.00
PrrBluet	0.00	0.00	0.30	0.60	0.90	1.00	1.00	1.00	0.80	0.50	0.20	0.00
PrCnflwr	0.00	0.00	0.40	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.00
TxSage	0.00	0.00	0.40	0.80	1.00	1.00	0.80	0.60	0.40	0.20	0.10	0.00
DoveWeed	0.10	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.40	0.20	0.10

Note: Monthly maximum growth rate is the monthly adjustment factor for maximum growth rate.

Table B15. Plant part productivity.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NlHckbry	0.00	0.00	0.00	0.10	1.00	0.00
TxPrsmmn	0.00	0.00	0.00	0.10	1.00	0.00
AsheJunp	0.00	0.00	0.00	0.10	1.00	0.00
ShRdOak	0.00	0.00	0.00	0.00	1.00	0.00
LvOak	0.00	0.00	0.00	0.00	1.00	0.00
CdrElm	0.00	0.00	0.00	0.00	1.00	0.00
Mesquite	0.00	0.00	0.00	0.10	1.00	0.10
Sotol	0.00	0.00	0.10	0.20	1.00	0.00
EvgSumac	0.00	0.00	0.00	0.30	1.00	0.00
GrnBriar	0.00	0.00	0.10	0.50	1.00	0.00
MtnGrape	0.00	0.00	0.00	0.10	1.00	0.00
AnnlGrs	0.00	0.00	0.10	0.30	1.00	0.00
OfThrAn	0.00	0.00	0.10	0.20	1.00	0.00
KRBluStm	0.00	0.00	0.20	0.40	1.00	0.00
SiBluStm	0.00	0.00	0.10	0.20	1.00	0.00
SdOtsGrm	0.00	0.00	0.10	0.30	1.00	0.00
HryGrm	0.00	0.00	0.10	0.30	1.00	0.00
BrmdaGrs	0.00	0.00	0.20	0.30	1.00	0.00
TxCupGrs	0.00	0.00	0.10	0.30	1.00	0.00
SpMuhly	0.00	0.00	0.10	0.20	1.00	0.00
LlBluStm	0.00	0.00	0.10	0.20	1.00	0.00
IndnGrs	0.00	0.00	0.10	0.20	1.00	0.00
TlDrpSd	0.00	0.00	0.10	0.20	1.00	0.00
TxWntGrs	0.00	0.00	0.20	0.30	1.00	0.00
CrlyMsqt	0.00	0.00	0.20	0.30	1.00	0.00
BrmWd	0.00	0.00	0.00	0.10	1.00	0.00
WdSedge	0.00	0.00	0.00	0.20	1.00	0.00
RbtTbaco	0.00	0.00	0.10	0.20	1.00	0.00
PrrBluet	0.00	0.00	0.20	0.20	1.00	0.00
PrCnflwr	0.00	0.00	0.10	0.20	1.00	0.00
TxSage	0.00	0.00	0.10	0.20	1.00	0.00
DoveWeed	0.00	0.00	0.00	0.30	1.00	0.00

Note: Plant part productivity is the relative productivity adjustment factor for different plant parts in calculating absolute growth percentage (effectively, photosynthetic biomass).

Table B16. Green-out plant part productivity.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NlHckbry	0.01	0.00	0.03	0.05	0.75	0.00
TxPrsmmn	0.01	0.00	0.03	0.05	0.75	0.00
AsheJunp	0.01	0.00	0.02	0.05	0.75	0.00
ShRdOak	0.01	0.00	0.02	0.05	0.75	0.00
LvOak	0.01	0.00	0.02	0.05	0.75	0.00
CdrElm	0.01	0.00	0.03	0.10	0.75	0.00
Mesquite	0.10	0.00	0.04	0.10	0.80	0.00
Sotol	0.05	0.00	0.10	0.30	1.00	0.00
EvgSumac	0.05	0.00	0.05	0.20	1.00	0.00
GrnBriar	0.10	0.00	0.20	0.50	1.00	0.00
MtnGrape	0.05	0.00	0.10	0.20	1.00	0.00
AnnlGrs	0.05	0.00	0.10	0.50	1.00	0.00
OfThrAn	0.00	0.00	0.50	0.50	1.00	0.00
KRBluStm	0.10	0.00	0.20	0.50	1.00	0.00
SiBluStm	0.05	0.00	0.10	0.50	1.00	0.00
SdOtsGrm	0.10	0.00	0.20	0.50	1.00	0.00
HryGrm	0.05	0.00	0.10	0.50	1.00	0.00
BrmdaGrs	0.10	0.00	0.10	0.50	1.00	0.00
TxCupGrs	0.05	0.00	0.10	0.50	1.00	0.00
SpMuhly	0.05	0.00	0.10	0.50	1.00	0.00
LlBluStm	0.05	0.00	0.10	0.50	1.00	0.00
IndnGrs	0.10	0.00	0.10	0.50	1.00	0.00
TlDrpSd	0.05	0.00	0.10	0.50	1.00	0.00
TxWntGrs	0.05	0.00	0.15	0.50	1.00	0.00
CrlyMsqt	0.05	0.00	0.10	0.50	1.00	0.00
BrmWd	0.00	0.00	0.05	0.50	1.00	0.00
WdSedge	0.10	0.00	0.30	0.50	1.00	0.00
RbtTbaco	0.00	0.00	0.20	0.50	1.00	0.00
PrrBluet	0.10	0.00	0.10	0.50	1.00	0.00
PrCnflwr	0.10	0.00	0.10	0.50	1.00	0.00
TxSage	0.00	0.00	0.20	0.50	1.00	0.00
DoveWeed	0.20	0.00	0.40	0.40	1.00	0.00

Note: Green-out plant part productivity is plant part productivity used during green-out months.

Table B17. Light competition factors.

Species	NlHckbry	TxPrsmn	AsheJunp	ShRdOak	LvOak	CdrElm	Mesquite	Sotol
NlHckbry	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
TxPrsmmn	0.05	0.00	0.00	0.05	0.10	0.05	0.00	0.00
AsheJunp	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00
ShRdOak	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
LvOak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CdrElm	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Mesquite	0.50	0.00	0.40	0.50	1.00	0.50	0.00	0.00
Sotol	0.20	0.20	0.10	0.25	0.50	0.20	0.10	0.00
EvgSumac	0.05	0.02	0.04	0.05	0.20	0.04	0.10	0.00
GrnBriar	0.05	0.03	0.05	0.10	0.15	0.03	0.10	0.00
MtnGrape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AnnlGrs	0.03	0.02	0.08	0.04	0.06	0.02	0.04	0.02
OfThrAn	0.12	0.10	0.05	0.12	0.16	0.10	0.06	0.08
KRBluStm	0.08	0.06	0.03	0.08	0.12	0.06	0.04	0.04
SiBluStm	0.08	0.06	0.03	0.08	0.12	0.06	0.04	0.00
SdOtsGrm	0.06	0.04	0.03	0.08	0.10	0.04	0.04	0.00
HryGrm	0.12	0.10	0.04	0.12	0.16	0.10	0.08	0.08
BrmdaGrs	0.12	0.10	0.04	0.12	0.16	0.10	0.08	0.08
TxCupGrs	0.03	0.02	0.02	0.04	0.06	0.02	0.04	0.02
SpMuhly	0.04	0.04	0.02	0.04	0.08	0.02	0.04	0.01
LlBluStm	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.00
IndnGrs	0.06	0.04	0.02	0.08	0.10	0.04	0.04	0.00
TlDrpSd	0.04	0.02	0.03	0.06	0.08	0.02	0.04	0.00
TxWntGrs	0.00	0.00	0.03	0.00	0.04	0.00	0.00	0.00
CrlyMsqt	0.12	0.10	0.04	0.12	0.16	0.10	0.08	0.08
BrmWd	0.08	0.06	0.04	0.10	0.12	0.06	0.00	0.04
WdSedge	0.04	0.04	0.02	0.04	0.08	0.02	0.04	0.01
RbtTbaco	0.04	0.02	0.02	0.06	0.08	0.02	0.02	0.02
PrrBluet	0.06	0.04	0.02	0.08	0.10	0.04	0.02	0.02
PrCnflwr	0.10	0.08	0.03	0.12	0.12	0.08	0.04	0.00
TxSage	0.04	0.04	0.02	0.06	0.08	0.02	0.04	0.02
DoveWeed	0.06	0.04	0.02	0.08	0.10	0.04	0.04	0.02
NlHckbry	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
TxPrsmmn	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
AsheJunp	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
ShRdOak	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
LvOak	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00

(sheet 1 of 4)

Species	NlHckbry	TxPrsmn	AsheJunp	ShRdOak	LvOak	CdrElm	Mesquite	Sotol
CdrElm	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Sotol	0.30	0.30	0.20	0.00	0.00	0.00	0.00	0.00
EvgSumac	0.00	0.10	0.30	0.00	0.00	0.00	0.00	0.00
GrnBriar	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.10
MtnGrape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AnnlGrs	0.06	0.04	0.04	0.00	0.00	0.00	0.08	0.06
OfThrAn	0.12	0.20	0.08	0.00	0.00	0.04	0.20	0.16
KRBluStm	0.12	0.16	0.08	0.00	0.00	0.00	0.12	0.10
SiBluStm	0.08	0.12	0.08	0.00	0.00	0.00	0.00	0.00
SdOtsGrm	0.08	0.00	0.08	0.00	0.00	0.00	0.02	0.00
HryGrm	0.16	0.24	0.08	0.00	0.00	0.08	0.24	0.20
BrmdaGrs	0.16	0.24	0.08	0.00	0.00	0.08	0.24	0.20
TxCupGrs	0.06	0.04	0.04	0.00	0.00	0.00	0.08	0.06
SpMuhly	0.08	0.16	0.04	0.00	0.00	0.02	0.08	0.06
LlBluStm	0.04	0.04	0.06	0.00	0.00	0.00	0.00	0.00
IndnGrs	0.10	0.04	0.06	0.00	0.00	0.00	0.00	0.00
TlDrpSd	0.08	0.04	0.04	0.00	0.00	0.00	0.00	0.00
TxWntGrs	0.04	0.04	0.00	0.00	0.00	0.02	0.06	0.04
CrlyMsqt	0.16	0.24	0.08	0.00	0.00	0.08	0.24	0.20
BrmWd	0.12	0.08	0.08	0.00	0.00	0.00	0.20	0.16
WdSedge	0.08	0.16	0.04	0.00	0.00	0.02	0.10	0.08
RbtTbaco	0.08	0.08	0.06	0.00	0.00	0.08	0.20	0.16
PrrBluet	0.10	0.08	0.06	0.00	0.00	0.04	0.12	0.08
PrCnflwr	0.12	0.04	0.08	0.00	0.00	0.00	0.08	0.04
TxSage	0.08	0.24	0.08	0.00	0.00	0.08	0.12	0.10
DoveWeed	0.10	0.08	0.06	0.00	0.00	0.04	0.12	0.08
NlHckbry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TxPrsmmn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AsheJunp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ShRdOak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LvOak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CdrElm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sotol	0.00	0.00	0.00	0.00	0.20	0.30	0.15	0.00
EvgSumac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GrnBriar	0.00	0.00	0.00	0.00	0.20	0.30	0.10	0.00

(sheet 2 of 4)

Species	NlHckbry	TxPrsmn	AsheJunp	ShRdOak	LvOak	CdrElm	Mesquite	Sotol
MtnGrape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AnnlGrs	0.00	0.00	0.00	0.00	0.12	0.16	0.08	0.00
OfThrAn	0.00	0.00	0.08	0.04	0.22	0.24	0.20	0.00
KRBluStm	0.00	0.00	0.02	0.00	0.05	0.16	0.12	0.00
SiBluStm	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00
SdOtsGrm	0.00	0.00	0.00	0.00	0.04	0.08	0.00	0.00
HryGrm	0.00	0.00	0.12	0.04	0.28	0.32	0.26	0.08
BrmdaGrs	0.00	0.00	0.12	0.04	0.28	0.32	0.26	0.08
TxCupGrs	0.00	0.00	0.00	0.00	0.12	0.16	0.08	0.00
SpMuhly	0.00	0.00	0.02	0.00	0.10	0.12	0.08	0.00
LlBluStm	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
IndnGrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TlDrpSd	0.00	0.00	0.00	0.00	0.04	0.12	0.00	0.00
TxWntGrs	0.00	0.00	0.00	0.00	0.02	0.08	0.06	0.00
CrlyMsqt	0.00	0.00	0.12	0.04	0.28	0.32	0.26	0.08
BrmWd	0.00	0.00	0.00	0.00	0.24	0.28	0.16	0.00
WdSedge	0.00	0.00	0.04	0.04	0.12	0.16	0.06	0.00
RbtTbaco	0.00	0.00	0.08	0.08	0.28	0.32	0.16	0.08
PrrBluet	0.00	0.00	0.04	0.00	0.24	0.28	0.08	0.00
PrCnflwr	0.00	0.00	0.00	0.00	0.05	0.20	0.04	0.00
TxSage	0.00	0.00	0.12	0.04	0.20	0.24	0.16	0.04
DoveWeed	0.00	0.00	0.04	0.00	0.24	0.28	0.08	0.00
NlHckbry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TxPrsmmn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AsheJunp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ShRdOak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LvOak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CdrElm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sotol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EvgSumac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GrnBriar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MtnGrape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AnnlGrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OfThrAn	0.00	0.12	0.00	0.00	0.00	0.04	0.00	0.00
KRBluStm	0.00	0.04	0.00	0.00	0.00	0.02	0.00	0.00
SiBluStm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SdOtsGrm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(sheet 3 of 4)

Species	NlHckbry	TxPrsmn	AsheJunp	ShRdOak	LvOak	CdrElm	Mesquite	Sotol
HryGrm	0.00	0.12	0.00	0.02	0.04	0.08	0.04	0.04
BrmdaGrs	0.00	0.12	0.00	0.02	0.04	0.08	0.04	0.04
TxCupGrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SpMuhly	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00
LlBluStm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IndnGrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TlDrpSd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TxWntGrs	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
CrlyMsqt	0.00	0.12	0.00	0.02	0.04	0.08	0.04	0.04
BrmWd	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
WdSedge	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00
RbtTbaco	0.00	0.12	0.00	0.00	0.04	0.16	0.04	0.04
PrrBluet	0.00	0.04	0.00	0.00	0.00	0.08	0.00	0.00
PrCnflwr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TxSage	0.00	0.08	0.00	0.00	0.00	0.08	0.00	0.00
DoveWeed	0.00	0.04	0.00	0.00	0.00	0.08	0.00	0.00

(sheet 4 of 4)

Note: Light competition factor is a suppressing effect factor on potential growth of one species (columns) on another (rows).

Table B18. Physiological controls.

Species	Growing Season Maximum Root:shoot	Growing Season Green-out Maximum Root:shoot	Maximum 1-month Seed Germination	Maximum 1st month Seedling Growth
NIHckbry	0.90	0.58	0.80	15
TxPrsmmn	1.00	0.51	0.70	9
AsheJunp	1.00	0.43	0.36	10
ShRdOak	1.30	0.38	0.90	9
LvOak	1.20	0.41	0.95	8
CdrElm	0.70	0.68	0.70	15
Mesquite	1.80	0.28	0.75	15
Sotol	5.40	0.09	0.75	15
EvgSumac	5.10	0.10	0.48	20
GrnBriar	2.00	0.25	0.60	30
MtnGrape	5.10	0.10	0.96	20
AnnlGrs	1.20	0.41	0.50	30
OfThrAn	1.40	0.35	0.90	40
KRBluStm	3.00	0.17	0.70	30
SiBluStm	2.40	0.21	0.55	30
SdOtsGrm	1.90	0.26	0.66	30
HryGrm	4.70	0.11	0.39	30
BrmdaGrs	2.90	0.27	0.82	30
TxCupGrs	1.20	0.41	0.50	30
SpMuhly	2.50	0.20	0.12	30
LIBluStm	2.40	0.21	0.53	30
IndnGrs	3.30	0.15	0.56	30
TlDrpSd	3.40	0.15	0.80	40
TxWntGrs	2.50	0.20	0.13	30
CrlyMsqt	4.70	0.11	0.62	30
BrmWd	0.90	0.56	0.95	30
WdSedge	3.50	0.15	0.35	30
RbtTbaco	3.90	0.13	0.50	40
PrrBluet	3.90	0.13	0.60	30
PrCnflwr	3.90	0.13	0.99	30
TxSage	3.00	0.17	0.44	40
DoveWeed	0.70	0.27	0.70	50

Note: Growing season maximum root:shoot is the maximum root to shoot ratio allowed during the growing season.

Growing season green-out maximum root:shoot is the maximum root to shoot ratio allowed during green-out months.

Maximum 1-month seed germination is the maximum proportion of seed bank seeds that can germinate in any one month.

Maximum 1st month seedling growth is the maximum factor increase in biomass for seedlings after germination.

Table B19. End of growing season dieback.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NIHckbry	0.01	0.05	0.01	0.05	1.00	1.00
TxPrsmmn	0.01	0.05	0.01	0.03	0.90	1.00
AsheJunp	0.01	0.10	0.01	0.03	0.33	1.00
ShRdOak	0.01	0.05	0.01	0.01	1.00	1.00
LvOak	0.01	0.05	0.01	0.01	0.50	1.00
CdrElm	0.01	0.05	0.02	0.03	1.00	1.00
Mesquite	0.01	0.05	0.01	0.03	1.00	1.00
Sotol	0.05	0.15	0.05	0.10	0.33	1.00
EvgSumac	0.03	0.10	0.02	0.20	0.50	1.00
GrnBriar	0.05	0.20	0.10	0.20	1.00	1.00
MtnGrape	0.02	0.10	0.03	0.20	1.00	1.00
AnnlGrs	1.00	1.00	1.00	1.00	1.00	1.00
OfThrAn	1.00	1.00	1.00	1.00	1.00	1.00
KRBluStm	0.10	0.20	0.05	0.60	0.95	1.00
SiBluStm	0.08	0.20	0.05	1.00	1.00	1.00
SdOtsGrm	0.08	0.20	0.05	1.00	1.00	1.00
HryGrm	0.10	0.20	0.10	1.00	1.00	1.00
BrmdaGrs	0.10	0.20	0.05	0.60	1.00	1.00
TxCupGrs	0.10	0.20	0.10	1.00	1.00	1.00
SpMuhly	0.10	0.20	0.10	1.00	1.00	1.00
LlBluStm	0.08	0.20	0.05	1.00	1.00	1.00
IndnGrs	0.06	0.20	0.05	0.95	1.00	1.00
TlDrpSd	0.08	0.20	0.05	1.00	1.00	1.00
TxWntGrs	0.10	0.20	0.08	1.00	1.00	1.00
CrlyMsqt	0.06	0.20	0.03	0.30	1.00	1.00
BrmWd	1.00	1.00	1.00	1.00	1.00	1.00
WdSedge	0.10	0.20	0.10	1.00	1.00	1.00
RbtTbaco	1.00	1.00	1.00	1.00	1.00	1.00
PrrBluet	0.20	0.40	0.15	1.00	1.00	1.00
PrCnflwr	0.20	0.40	0.20	1.00	1.00	1.00
TxSage	0.20	0.25	0.20	1.00	1.00	1.00
DoveWeed	0.50	0.60	0.50	0.90	0.90	1.00

Note: End of growing season dieback is the proportion of each plant component that dies at winter dormancy.

Table B20. Dieback fate.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
NlHckbry	-1	-1	7	7	0	0
TxPrsmmn	-1	-1	7	7	0	0
AsheJunp	-1	-1	7	7	0	0
ShRdOak	-1	-1	7	7	0	0
LvOak	-1	-1	7	7	0	0
CdrElm	-1	-1	7	7	0	0
Mesquite	-1	-1	7	7	0	0
Sotol	-1	-1	7	7	8	0
EvgSumac	-1	-1	7	7	0	0
GrnBriar	-1	-1	0	7	0	0
MtnGrape	-1	-1	7	7	0	0
AnnlGrs	-1	-1	0	7	8	0
OfThrAn	-1	-1	0	7	8	0
KRBluStm	-1	-1	0	0	8	0
SiBluStm	-1	-1	0	7	8	0
SdOtsGrm	-1	-1	0	7	8	0
HryGrm	-1	-1	0	7	8	0
BrmdaGrs	-1	-1	0	0	8	0
TxCupGrs	-1	-1	0	7	8	0
SpMuhly	-1	-1	0	7	8	0
LIBluStm	-1	-1	0	7	8	0
IndnGrs	-1	-1	0	7	8	0
TlDrpSd	-1	-1	0	7	8	0
TxWntGrs	-1	-1	0	7	8	0
CrlyMsqt	-1	-1	0	0	8	0
BrmWd	-1	-1	7	7	8	0
WdSedge	-1	-1	0	7	8	0
RbtTbaco	-1	-1	0	7	8	0
PrrBluet	-1	-1	0	7	8	0
PrCnflwr	-1	-1	7	7	8	0
TxSage	-1	-1	0	7	0	0
DoveWeed	-1	-1	0	7	8	0

Note: Dieback fate indicates where dieback biomass is transferred.

-1 organic matter in the soil profile

0 surface litter

7 standing dead stems

8 standing dead leaves

Table B21. Fuel loads.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0.00	0.00	0.25	0.50	1.00	1.00	0.75	1.50	0.00	1.00	1.00
TxPrsmmn	0.00	0.00	0.30	0.50	1.00	1.00	0.75	1.50	0.00	1.00	1.00
AsheJunp	0.00	0.00	0.50	0.75	2.00	1.00	1.00	4.00	0.00	2.00	1.00
ShRdOak	0.00	0.00	0.25	0.50	1.00	0.75	0.75	1.50	0.00	1.00	0.90
LvOak	0.00	0.00	0.25	0.50	1.00	0.75	0.75	1.50	0.00	1.00	0.90
CdrElm	0.00	0.00	0.25	0.50	1.00	1.00	0.75	1.50	0.00	1.00	1.00
Mesquite	0.00	0.00	0.10	0.20	0.80	0.60	0.80	1.00	0.00	0.80	0.80
Sotol	0.00	0.00	0.25	0.50	0.75	1.00	1.00	1.50	0.00	0.75	1.00
EvgSumac	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.50	0.00	1.00	1.00
GrnBriar	0.00	0.00	0.00	0.80	0.90	1.00	1.00	1.50	0.00	1.00	1.00
MtnGrape	0.00	0.00	0.50	1.00	1.00	1.00	1.50	1.00	0.00	1.00	1.00
AnnlGrs	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
OfThrAn	0.00	0.00	0.40	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
KRBluStm	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
SiBluStm	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
SdOtsGrm	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
HryGrm	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
BrmdaGrs	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
TxCupGrs	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
SpMuhly	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
LlBluStm	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
IndnGrs	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
TlDrpSd	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
TxWntGrs	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
CrlyMsqt	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
BrmWd	0.00	0.00	0.00	1.00	1.50	1.00	1.50	2.00	0.00	1.00	1.00
WdSedge	0.00	0.00	0.00	0.90	1.00	1.00	1.50	1.50	0.00	1.00	1.00
RbtTbaco	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
PrrBluet	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
PrCnflwr	0.00	0.00	0.00	1.00	1.00	1.00	1.50	1.50	0.00	1.00	1.00
TxSage	0.00	0.00	0.00	1.00	1.10	1.00	1.50	1.50	0.00	1.00	1.00
DoveWeed	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00

Note: Fuel load is the relative contribution adjustment for each plant component biomass to total fuel loads.

Table B22. Plant component loss to fire.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NIHckbry	0.00	0.00	0.01	0.05	0.05	0.00	0.05	0.05	0.00	1.00	0.50
TxPrsmmn	0.00	0.00	0.02	0.10	0.10	0.03	0.10	0.10	0.00	1.00	0.50
AsheJunp	0.00	0.00	0.01	0.05	0.20	0.05	0.35	0.40	0.00	1.00	0.50
ShRdOak	0.00	0.00	0.01	0.05	0.05	0.00	0.05	0.05	0.00	1.00	0.90
LvOak	0.00	0.00	0.01	0.05	0.10	0.00	0.10	0.10	0.00	1.00	0.95
CdrElm	0.00	0.00	0.01	0.05	0.05	0.00	0.05	0.05	0.00	1.00	0.50
Mesquite	0.00	0.00	0.01	0.05	0.10	0.01	0.10	0.20	0.00	1.00	0.25
Sotol	0.00	0.00	0.40	0.50	0.80	0.50	1.00	1.00	0.00	0.90	0.50
EvgSumac	0.00	0.00	0.60	0.40	0.50	0.40	0.80	0.90	0.00	1.00	0.50
GrnBriar	0.00	0.00	0.50	0.50	0.50	0.80	0.80	0.50	0.00	1.00	0.40
MtnGrape	0.00	0.00	0.05	0.00	0.00	0.00	0.20	0.10	0.00	1.00	0.50
AnnlGrs	0.00	0.00	0.40	0.90	1.00	1.00	1.00	1.00	0.00	1.00	0.50
OfThrAn	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
KRBluStm	0.00	0.00	0.30	0.90	1.00	1.00	1.00	1.00	0.00	1.00	0.50
SiBluStm	0.00	0.00	0.40	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
SdOtsGrm	0.05	0.00	0.30	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
HryGrm	0.00	0.00	0.40	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
BrmdaGrs	0.00	0.00	0.15	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.40
TxCupGrs	0.00	0.00	0.40	0.90	1.00	1.00	1.00	1.00	0.00	1.00	0.50
SpMuhly	0.00	0.00	0.40	0.95	1.00	1.00	1.00	1.00	0.00	1.00	0.50
LlBluStm	0.00	0.00	0.30	0.95	1.00	1.00	1.00	1.00	0.00	1.00	0.50
IndnGrs	0.00	0.00	0.30	0.90	1.00	1.00	1.00	1.00	0.00	1.00	0.50
TlDrpSd	0.00	0.00	0.30	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.30
TxWntGrs	0.00	0.00	0.30	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.40
CrlyMsqt	0.00	0.00	0.15	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.40
BrmWd	0.00	0.00	0.80	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.30
WdSedge	0.00	0.00	0.30	0.90	0.90	1.00	1.00	1.00	0.00	0.90	0.50
RbtTbaco	0.00	0.00	0.70	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
PrrBluet	0.00	0.00	0.40	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.40
PrCnflwr	0.00	0.00	0.90	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.40
TxSage	0.00	0.00	0.60	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50
DoveWeed	0.00	0.00	0.80	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.60

Note: Plant component loss to fire is the proportion of component biomass lost to moderate fires.

Table B23. Insect preference and competition matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NIHckbry	0,0	0,0	0,1	0,1	1,1	10,1	0,1	13,1	0,1	1,1	0,1
TxPrsmmn	0,0	0,0	0,1	0,1	5,1	6,1	0,1	0,1	0,1	4,1	0,1
AsheJunp	0,0	0,0	0,0	0,1	12,1	11,1	0,1	0,1	0,0	11,1	0,1
ShRdOak	0,0	0,0	0,1	0,1	3,1	0,1	0,1	0,1	0,1	3,1	0,1
LvOak	0,0	0,0	0,1	0,1	10,1	0,1	0,1	0,1	0,1	9,1	0,1
CdrElm	0,0	0,0	0,1	0,1	1,1	10,1	0,1	13,1	0,1	1,1	0,1
Mesquite	0,0	0,0	0,0	0,0	12,1	11,1	0,0	13,1	0,0	12,1	0,0
Sotol	0,0	0,0	11,1	11,1	10,1	3,1	0,1	0,1	0,1	10,1	0,1
EvgSumac	0,0	0,0	0,0	0,1	4,1	4,1	0,1	0,1	0,1	3,1	0,1
GrnBriar	0,0	0,0	0,0	13,1	8,1	5,1	0,1	0,1	0,1	7,1	0,1
MtnGrape	0,0	0,0	0,0	0,1	1,1	1,1	0,1	13,1	0,1	1,1	0,1
AnnlGrs	0,0	0,0	7,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
OfThrAn	0,0	0,0	9,1	7,1	6,1	8,1	0,1	13,1	0,1	4,1	0,1
KRBluStm	0,0	0,0	7,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
SiBluStm	0,0	0,0	8,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
SdOtsGrm	0,0	0,0	8,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
HryGrm	0,0	0,0	8,1	5,1	5,1	5,1	0,1	13,1	0,1	3,1	0,1
BrmdaGrs	0,0	0,0	6,1	6,1	3,1	4,1	11,1	7,1	0,0	2,1	0,0
TxCupGrs	0,0	0,0	7,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
SpMuhly	0,0	0,0	7,1	4,1	4,1	4,1	0,1	13,1	0,1	2,1	0,1
LIBluStm	0,0	0,0	8,1	7,1	1,1	6,1	0,1	13,1	0,1	1,1	0,1
IndnGrs	0,0	0,0	8,1	7,1	1,1	3,1	0,1	13,1	0,1	1,1	0,1
TlDrpSd	0,0	0,0	8,1	5,1	4,1	5,1	0,1	13,1	0,1	3,1	0,1
TxWntGrs	0,0	0,0	7,1	5,1	4,1	5,1	0,1	13,1	0,1	2,1	0,1
CrlyMsqt	0,0	0,0	6,1	6,1	3,1	4,1	11,1	7,1	0,0	2,1	0,0
BrmWd	0,0	0,0	12,1	8,1	7,1	6,1	0,1	0,1	0,1	6,1	0,1
WdSedge	0,0	0,0	8,1	4,1	1,1	4,1	0,1	13,1	0,1	1,1	0,1
RbtTbaco	0,0	0,0	7,1	4,1	2,1	2,1	0,1	13,1	0,1	1,1	0,1
PrrBluet	0,0	0,0	8,1	4,1	2,1	2,1	0,1	13,1	0,1	1,1	0,1
PrCnflwr	0,0	0,0	9,1	4,1	2,1	1,1	0,1	0,1	0,1	1,1	0,1
TxSage	0,0	0,0	9,1	4,1	2,1	3,1	0,1	13,1	0,1	1,1	0,1
DoveWeed	0,2	0,2	3,1	2,1	1,1	2,1	4,1	2,1	0,3	1,1	0,2

Note: Preference is insect diet preference ranking for each plant component for each species, while competition is the relative competitive ability of insects in obtaining the plant component for each species.

Table B24. Insect accessibility matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0	0	0	50	100	100	50	100	0	100	5
TxPrsmmn	0	0	0	50	100	100	50	100	0	100	20
AsheJunp	0	0	0	50	100	100	50	100	0	100	10
ShRdOak	0	0	0	50	100	100	50	100	0	100	90
LvOak	0	0	0	50	100	100	50	100	0	100	90
CdrElm	0	0	0	50	100	100	50	100	0	100	50
Mesquite	0	0	80	100	100	100	100	100	0	100	50
Sotol	0	0	50	75	100	100	75	100	0	100	10
EvgSumac	0	0	10	50	100	100	50	100	0	100	10
GrnBriar	0	0	100	100	100	100	100	100	0	100	5
MtnGrape	0	0	100	40	100	100	40	100	0	100	10
AnnlGrs	0	0	60	100	100	100	100	100	0	100	10
OfThrAn	0	0	60	100	100	100	100	100	0	100	5
KRBluStm	0	0	60	90	100	100	100	100	0	100	10
SiBluStm	0	0	40	100	100	100	100	100	0	100	10
SdOtsGrm	0	0	40	100	100	100	100	100	0	100	10
HryGrm	0	0	60	100	100	100	100	100	0	100	10
BrmdaGrs	0	0	60	90	100	100	100	100	0	100	10
TxCupGrs	0	0	60	100	100	100	100	100	0	100	10
SpMuhly	0	0	60	100	100	100	100	100	0	100	5
LlBluStm	0	0	40	90	90	90	90	90	0	90	10
IndnGrs	0	0	40	100	100	100	100	100	0	100	10
TlDrpSd	0	0	40	100	100	100	100	100	0	100	5
TxWntGrs	0	0	40	100	100	100	100	100	0	100	5
CrlyMsqt	0	0	60	90	100	100	100	100	0	100	10
BrmWd	0	0	90	90	90	90	90	90	0	90	0
WdSedge	0	0	60	90	90	90	90	90	0	90	5
RbtTbaco	0	0	90	90	90	90	90	90	0	90	0
PrrBluet	0	0	90	90	90	90	90	90	0	90	0
PrCnflwr	0	0	90	90	90	90	90	90	0	90	0
TxSage	0	0	90	90	90	90	90	90	0	90	0
DoveWeed	0	0	50	100	100	100	100	100	0	100	30

Note: Accessibility is the proportion of the total component biomass that is accessible for consumption by insects.

Table B25. Rabbit preference and competition matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0,0	0,0	12,2	8,4	4,4	7,4	0,0	9,4	0,0	1,2	8,2
TxPrsmmn	0,0	0,0	13,2	9,4	6,4	5,4	0,0	10,4	0,0	5,2	6,2
AsheJunp	0,0	0,0	0,0	15,4	14,4	15,4	0,0	16,4	0,0	12,2	15,2
ShRdOak	0,0	0,0	0,0	10,4	7,4	6,4	0,0	11,4	0,0	5,2	6,2
LvOak	0,0	0,0	0,0	14,4	8,4	6,4	0,0	12,4	0,0	6,2	6,2
CdrElm	0,0	0,0	12,2	8,4	4,4	7,4	0,0	9,4	0,0	2,2	7,2
Mesquite	0,0	0,0	19,2	17,2	16,2	7,2	0,0	18,2	0,0	15,2	11,2
Sotol	0,0	0,0	8,2	8,4	7,2	2,4	0,0	0,0	0,0	6,2	0,0
EvgSumac	0,0	0,0	13,2	9,4	7,4	6,4	0,0	10,4	0,0	6,2	0,0
GrnBriar	0,0	0,0	11,2	7,2	6,2	7,3	14,2	8,2	0,0	5,2	0,0
MtnGrape	0,0	0,0	0,0	8,4	4,4	2,4	0,0	9,4	0,0	1,2	0,0
AnnlGrs	0,0	0,0	4,2	3,2	2,2	2,2	9,2	4,2	0,0	1,2	0,0
OfThrAn	0,0	0,0	7,2	6,2	5,2	6,2	0,0	8,2	0,0	4,2	0,0
KRBluStm	0,0	0,0	4,2	4,2	3,2	3,2	9,2	5,2	0,0	2,2	0,0
SiBluStm	0,0	0,0	5,2	4,2	3,2	4,2	10,2	5,2	0,0	2,2	0,0
SdOtsGrm	0,0	0,0	5,2	4,2	3,2	3,2	9,2	5,2	0,0	2,2	0,0
HryGrm	0,0	0,0	5,2	4,2	3,2	4,2	9,2	6,2	0,0	2,2	0,0
BrmdaGrs	0,0	0,0	4,2	4,2	2,2	2,2	5,2	3,2	0,0	2,2	0,0
TxCupGrs	0,0	0,0	4,2	3,2	2,2	2,2	9,2	4,2	0,0	1,2	0,0
SpMuhly	0,0	0,0	5,2	4,2	3,2	4,2	9,2	5,2	0,0	2,2	0,0
LlBluStm	0,0	0,0	6,2	5,2	3,2	5,2	10,2	5,2	0,0	2,2	0,0
IndnGrs	0,0	0,0	5,2	4,2	3,2	2,2	10,2	5,2	0,0	2,2	0,0
TlDrpSd	0,0	0,0	6,2	5,2	3,2	5,2	10,2	5,2	0,0	2,2	0,0
TxWntGrs	0,0	0,0	6,2	5,2	3,2	5,2	10,2	6,2	0,0	2,2	0,0
CrlyMsqt	0,0	0,0	4,2	4,2	2,2	2,2	5,2	3,2	0,0	2,2	0,0
BrmWd	0,0	0,0	9,2	7,2	5,2	3,2	11,2	8,2	0,0	4,2	0,0
WdSedge	0,0	0,0	5,2	3,2	2,2	3,2	10,2	4,2	0,0	1,2	0,0
RbtTbaco	0,0	0,0	4,2	2,2	1,2	2,2	8,2	4,2	0,0	1,2	0,0
PrrBluet	0,0	0,0	6,2	4,2	1,2	4,2	9,2	5,2	0,0	1,2	0,0
PrCnflwr	0,0	0,0	5,2	3,2	1,2	2,2	9,2	4,2	0,0	1,2	0,0
TxSage	0,0	0,0	5,2	2,2	1,2	2,2	8,2	5,2	0,0	1,2	0,0
DoveWeed	7,1	7,1	8,2	3,2	1,2	2,2	5,2	4,2	0,2	1,2	0,1

Note: Preference is rabbit diet preference ranking for each plant component for each species, while competition is the relative competitive ability of rabbits in obtaining the plant component for each species.

Table B26. Rabbit accessibility matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NIHckbry	5	0	5	1	2	1	1	1	0	100	5
TxPrsmmn	5	0	5	3	5	3	3	3	0	100	40
AsheJunp	0	0	0	0	0	0	0	0	0	0	0
ShRdOak	5	0	5	1	1	0	1	1	0	100	40
LvOak	0	0	0	0	0	0	0	0	0	0	0
CdrElm	5	0	5	1	1	0	1	1	0	100	10
Mesquite	5	0	10	5	5	1	5	5	0	90	70
Sotol	5	0	100	100	100	100	100	100	0	100	5
EvgSumac	5	0	20	25	30	0	25	30	0	100	2
GrnBriar	5	0	100	50	50	30	50	50	0	100	0
MtnGrape	5	0	2	0	0	0	0	0	0	100	5
AnnlGrs	5	0	95	100	100	100	100	100	0	100	5
OfThrAn	5	0	90	100	100	100	100	100	0	100	0
KRBluStm	5	0	95	95	100	100	100	100	0	100	5
SiBluStm	5	0	80	100	100	100	100	100	0	100	0
SdOtsGrm	10	0	95	100	100	100	100	100	0	100	5
HryGrm	5	0	95	100	100	100	100	100	0	100	0
BrmdaGrs	5	0	95	95	100	100	100	100	0	100	5
TxCupGrs	5	0	95	100	100	100	100	100	0	100	5
SpMuhly	5	0	95	100	100	100	100	100	0	100	0
LlBluStm	5	0	80	90	90	90	90	90	0	90	0
IndnGrs	5	0	80	100	100	100	100	100	0	100	5
TlDrpSd	5	0	85	100	100	100	100	100	0	100	0
TxWntGrs	5	0	90	100	100	100	100	100	0	100	0
CrlyMsqt	5	0	95	95	100	100	100	100	0	100	5
BrmWd	5	0	90	90	90	90	90	90	0	90	0
WdSedge	5	0	80	90	90	90	90	90	0	90	0
RbtTbaco	5	0	90	90	90	90	90	90	0	90	0
PrrBluet	5	0	95	90	90	90	90	90	0	90	0
PrCnflwr	5	0	90	90	90	90	90	90	0	90	0
TxSage	5	0	90	90	90	90	90	90	0	90	0
DoveWeed	10	0	100	100	100	90	100	100	10	80	0

Note: Accessibility is the proportion of the total component biomass that is accessible for consumption by rabbits.

Table B27. Deer preference and competition matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0,0	0,0	10,2	8,2	2,2	2,2	0,0	6,2	0,0	1,3	0,0
TxPrsmmn	0,0	0,0	0,0	9,2	4,2	3,2	0,0	8,2	0,0	3,3	4,3
AsheJunp	0,0	0,0	0,0	12,2	10,2	10,2	0,0	12,2	0,0	9,3	0,0
ShRdOak	0,0	0,0	0,0	10,2	5,2	6,2	0,0	7,2	0,0	4,3	6,3
LvOak	0,0	0,0	0,0	11,2	6,2	6,2	0,0	8,2	0,0	5,3	6,3
CdrElm	0,0	0,0	0,0	9,2	3,2	3,2	0,0	6,2	0,0	3,3	0,0
Mesquite	0,0	0,0	0,0	12,2	10,2	10,2	0,0	12,2	0,0	9,3	0,0
Sotol	0,0	0,0	9,3	9,2	9,3	2,2	0,0	12,2	0,0	8,3	0,0
EvgSumac	0,0	0,0	12,2	11,2	7,2	6,2	0,0	9,2	0,0	6,3	0,0
GrnBriar	0,0	0,0	10,3	8,3	6,3	7,3	13,3	10,3	0,0	5,3	0,0
MtnGrape	0,0	0,0	0,0	10,2	4,2	1,2	0,0	7,2	0,0	3,3	0,0
AnnlGrs	0,0	0,0	5,3	4,3	4,3	3,3	5,3	7,3	0,0	4,3	0,0
OfThrAn	0,0	0,0	11,3	9,3	9,3	9,3	10,3	9,3	0,0	9,3	0,0
KRBluStm	0,0	0,0	6,3	5,3	4,3	5,3	6,3	7,3	0,0	4,3	0,0
SiBluStm	0,0	0,0	9,3	8,3	7,3	8,3	9,3	8,3	0,0	7,3	0,0
SdOtsGrm	0,0	0,0	7,3	6,3	5,3	5,3	7,3	7,3	0,0	5,3	0,0
HryGrm	0,0	0,0	6,3	5,3	5,3	5,3	5,3	7,3	0,0	5,3	0,0
BrmdaGrs	0,0	0,0	6,3	6,3	6,3	6,3	6,3	6,3	0,0	5,3	0,0
TxCupGrs	0,0	0,0	5,3	4,3	4,3	3,3	5,3	7,3	0,0	4,3	0,0
SpMuhly	0,0	0,0	7,3	6,3	6,3	6,3	7,3	8,3	0,0	6,3	0,0
LlBluStm	0,0	0,0	9,3	8,3	7,3	8,3	9,3	8,3	0,0	7,3	0,0
IndnGrs	0,0	0,0	8,3	7,3	6,3	3,3	8,3	8,3	0,0	6,3	0,0
TlDrpSd	0,0	0,0	9,3	8,3	8,3	8,3	9,3	9,3	0,0	8,3	0,0
TxWntGrs	0,0	0,0	6,3	5,3	5,3	5,3	5,3	8,3	0,0	5,3	0,0
CrlyMsqt	0,0	0,0	6,3	6,3	6,3	6,3	6,3	6,3	0,0	5,3	0,0
BrmWd	0,0	0,0	10,3	9,3	8,3	4,3	13,3	8,3	0,0	7,3	0,0
WdSedge	0,0	0,0	5,3	3,3	3,3	3,3	5,3	8,3	0,0	3,3	0,0
RbtTbaco	0,0	0,0	2,3	1,3	1,3	1,3	5,3	6,3	0,0	1,3	0,0
PrrBluet	0,0	0,0	4,3	2,3	2,3	2,3	5,3	6,3	0,0	2,3	0,0
PrCnflwr	0,0	0,0	3,3	1,3	1,3	1,3	7,3	6,3	0,0	1,3	0,0
TxSage	0,0	0,0	2,3	1,3	1,3	1,3	5,3	6,3	0,0	1,3	0,0
DoveWeed	0,0	0,0	4,3	2,3	2,3	2,3	5,3	6,3	0,0	2,3	0,0

Note: Preference is deer diet preference ranking for each plant component for each species, while competition is the relative competitive ability of deer in obtaining the plant component for each species.

Table B28. Deer accessibility matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NIHckbry	0	0	5	40	40	20	40	40	0	100	0
TxPrsmmn	0	0	10	60	60	40	60	60	0	100	10
AsheJunp	0	0	5	60	50	30	60	50	0	100	5
ShRdOak	0	0	5	30	20	10	30	20	0	100	75
LvOak	0	0	5	50	40	20	50	40	0	100	75
CdrElm	0	0	5	40	40	20	40	40	0	100	5
Mesquite	0	0	5	60	50	30	60	50	0	100	5
Sotol	0	0	60	90	100	100	90	100	0	100	5
EvgSumac	0	0	20	80	80	70	80	80	0	100	5
GrnBriar	0	0	100	100	100	100	100	100	0	95	0
MtnGrape	0	0	20	5	5	0	5	5	0	100	10
AnnlGrs	0	0	80	100	100	100	100	100	0	90	5
OfThrAn	0	0	90	100	100	100	100	100	0	90	0
KRBluStm	0	0	80	80	95	100	80	95	0	90	0
SiBluStm	0	0	70	100	100	100	100	100	0	90	0
SdOtsGrm	0	0	80	100	100	100	100	100	0	90	5
HryGrm	0	0	80	100	95	100	100	100	0	90	0
BrmdaGrs	0	0	80	90	90	100	90	90	0	90	0
TxCupGrs	0	0	80	100	100	100	100	100	0	90	5
SpMuhly	0	0	70	100	100	100	100	100	0	90	0
LIBluStm	0	0	70	90	90	90	90	90	0	90	0
IndnGrs	0	0	65	100	100	100	100	100	0	90	5
TlDrpSd	0	0	75	100	100	100	100	100	0	90	0
TxWntGrs	0	0	80	100	95	100	100	100	0	90	0
CrlyMsqt	0	0	80	90	90	100	90	90	0	90	0
BrmWd	0	0	90	90	90	90	90	90	0	95	0
WdSedge	0	0	80	90	90	90	90	90	0	80	0
RbtTbaco	0	0	90	90	90	90	90	90	0	95	0
PrrBluet	0	0	95	95	90	90	90	90	0	95	0
PrCnflwr	0	0	90	90	90	90	90	90	0	95	0
TxSage	0	0	90	90	90	90	90	90	0	95	0
DoveWeed	0	0	95	95	90	90	90	90	0	95	0

Note: Accessibility is the proportion of the total component biomass that is accessible for consumption by deer.

Table B29. Cattle preference and competition matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0,0	0,0	0,0	6,3	6,3	6,3	0,0	10,3	0,0	6,4	0,0
TxPrsmmn	0,0	0,0	13,4	8,3	8,3	5,3	0,0	12,3	0,0	8,4	0,0
AsheJunp	0,0	0,0	15,4	14,3	14,3	14,3	0,0	15,3	0,0	14,4	0,0
ShRdOak	0,0	0,0	0,0	9,3	9,3	9,3	0,0	11,3	0,0	9,4	0,0
LvOak	0,0	0,0	0,0	10,3	10,3	10,3	0,0	12,3	0,0	10,4	0,0
CdrElm	0,0	0,0	0,0	7,3	7,3	7,3	0,0	9,3	0,0	7,4	0,0
Mesquite	0,0	0,0	15,4	14,3	14,3	14,3	0,0	15,3	0,0	14,4	0,0
Sotol	0,0	0,0	12,4	12,3	12,4	7,3	0,0	15,3	0,0	12,4	0,0
EvgSumac	0,0	0,0	0,0	11,3	11,3	11,3	0,0	13,3	0,0	11,4	0,0
GrnBriar	0,0	0,0	0,0	10,4	9,4	10,4	12,4	12,4	0,0	9,4	0,0
MtnGrape	0,0	0,0	0,0	7,3	7,3	7,3	0,0	9,3	0,0	7,4	0,0
AnnlGrs	0,0	0,0	2,4	1,4	1,4	1,4	3,4	3,4	0,0	1,4	0,0
OfThrAn	0,0	0,0	6,4	5,4	5,4	5,4	6,4	6,4	0,0	5,4	0,0
KRBluStm	0,0	0,0	4,4	3,4	3,4	3,4	4,4	4,4	0,0	3,4	0,0
SiBluStm	0,0	0,0	4,4	3,4	3,4	3,4	4,4	4,4	0,0	3,4	0,0
SdOtsGrm	0,0	0,0	2,4	1,4	1,4	1,4	3,4	3,4	0,0	1,4	0,0
HryGrm	0,0	0,0	3,4	2,4	2,4	2,4	2,4	2,4	0,0	2,4	0,0
BrmdaGrs	0,0	0,0	2,4	1,4	1,4	1,4	2,4	2,4	0,0	1,4	0,0
TxCupGrs	0,0	0,0	2,4	1,4	1,4	1,4	3,4	3,4	0,0	1,4	0,0
SpMuhly	0,0	0,0	4,4	3,4	3,4	3,4	4,4	4,4	0,0	3,4	0,0
LlBluStm	0,0	0,0	4,4	3,4	3,4	3,4	4,4	4,4	0,0	3,4	0,0
IndnGrs	0,0	0,0	2,4	1,4	1,4	1,4	3,4	3,4	0,0	1,4	0,0
TlDrpSd	0,0	0,0	4,4	3,4	3,4	3,4	4,4	4,4	0,0	3,4	0,0
TxWntGrs	0,0	0,0	2,4	1,4	1,4	1,4	3,4	3,4	0,0	1,4	0,0
CrlyMsqt	0,0	0,0	2,4	1,4	1,4	1,4	2,4	2,4	0,0	1,4	0,0
BrmWd	0,0	0,0	11,4	10,4	10,4	9,4	15,4	15,4	0,0	9,4	0,0
WdSedge	0,0	0,0	4,4	3,4	3,4	3,4	5,4	5,4	0,0	3,4	0,0
RbtTbaco	0,0	0,0	7,4	6,4	6,4	6,4	8,4	8,4	0,0	6,4	0,0
PrrBluet	0,0	0,0	6,4	5,4	5,4	5,4	7,4	7,4	0,0	5,4	0,0
PrCnflwr	0,0	0,0	5,4	4,4	4,4	3,4	6,4	6,4	0,0	4,4	0,0
TxSage	0,0	0,0	6,4	5,4	5,4	5,4	7,4	7,4	0,0	5,4	0,0
DoveWeed	0,3	0,3	8,3	6,3	6,3	6,3	7,3	7,3	0,1	4,3	3,3

Note: Preference is cattle diet preference ranking for each plant component for each species, while competition is the relative competitive ability of cattle in obtaining the plant component for each species.

Table B30. Cattle accessibility matrix.

Species	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
NlHckbry	0	0	10	40	40	20	40	40	0	90	0
TxPrsmmn	0	0	20	60	60	40	60	60	0	90	5
AsheJunp	0	0	0	0	0	0	0	0	0	0	0
ShRdOak	0	0	5	10	10	5	10	10	0	90	40
LvOak	0	0	0	0	0	0	0	0	0	0	0
CdrElm	0	0	10	10	10	5	10	10	0	90	0
Mesquite	0	0	20	60	60	30	60	60	0	90	0
Sotol	0	0	90	100	100	100	100	100	0	90	0
EvgSumac	0	0	20	80	80	70	80	80	0	90	0
GrnBriar	0	0	30	90	90	100	90	90	0	20	0
MtnGrape	0	0	50	10	5	5	10	10	0	90	5
AnnlGrs	0	0	50	100	90	100	100	90	0	50	0
OfThrAn	0	0	50	90	90	100	90	90	0	25	0
KRBluStm	0	0	10	40	80	100	40	80	0	50	0
SiBluStm	0	0	40	95	90	100	95	90	0	50	0
SdOtsGrm	0	0	50	90	90	100	90	90	0	50	0
HryGrm	0	0	10	90	70	100	90	70	0	25	0
BrmdaGrs	0	0	10	40	70	90	40	70	0	50	0
TxCupGrs	0	0	50	100	90	100	100	90	0	50	0
SpMuhly	0	0	10	90	70	100	90	70	0	25	0
LlBluStm	0	0	40	90	90	90	90	90	0	50	0
IndnGrs	0	0	30	90	90	100	90	90	0	50	0
TlDrpSd	0	0	45	100	90	100	90	90	0	50	0
TxWntGrs	0	0	30	90	70	100	90	70	0	50	0
CrlyMsqt	0	0	10	40	70	90	40	70	0	50	0
BrmWd	0	0	90	90	90	100	90	90	0	20	0
WdSedge	0	0	10	90	60	90	90	60	0	20	0
RbtTbaco	0	0	20	80	80	90	80	80	0	20	0
PrrBluet	0	0	50	80	80	90	80	80	0	20	0
PrCnflwr	0	0	90	90	90	90	90	90	0	20	0
TxSage	0	0	90	90	90	90	90	90	0	20	0
DoveWeed	0	0	70	90	90	90	90	90	0	50	0

Note: Accessibility is the proportion of the total component biomass that is accessible for consumption by cattle.

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14. ABSTRACT

The impact of hydrological alteration on vegetation and of vegetation on water quality can be greatly facilitated by linking existing water engines with general ecosystem models designed to make long-term projections of ecosystem dynamics. This development effort investigated the linkage of soil moisture between the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model and the Ecological Dynamics Simulation (EDYS) model. Conceptually, the EDYS and GSSHA models are well-suited for linkage given that they are both designed to simulate physical or ecological processes at multiple spatial and temporal scales. In particular, EDYS computes small-scale flows (precipitation, interception, evaporation, infiltration, transpiration, and nutrient and contaminant uptake) on a daily basis, and can thereby provide much more accurate estimates of evapotranspiration and water, nutrient, and contaminant uptake by vegetation than would ordinarily be available for calibration of hydrologic models. GSSHA and associated groundwater codes can then provide more accurate estimates of large-scale hydrological and transport processes back to EDYS to effect a system-wide assessment or projection. The long-term objective of this linkage between EDYS and GSSHA is to collaborate with other SWWRP product lines and provide a dynamic eco-hydro modeling capability for regional applications (i.e., the Upper Mississippi, the Everglades, or the Nueces Basin).

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